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PALEONTOLOGY

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## OSTRACODA OF SAN ANTONIO BAY, TEXAS*


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ABSTRACT.—Three principal ostracode biofacies and three subfacies can be recognized in San Antonio Bay and the adjacent barrier island and open Gulf, Calhoun County, Texas. These include a bay facies, a fluvial and prodelta facies, and an open Gulf facies. The bay facies contains a midbay subfacies, a lower bay subfacies, and a marginal and barrier island marsh subfacies. The facies and subfacies are controlled by prevailing salinity differences, available food supply, and perhaps to a lesser extent by the type of bottom.

Forty-seven species, one variety and one subspecies of Ostracoda are described and illustrated. Fifteen of the species are known to occur as fossils and eight are present as far back as the Miocene.


### INTRODUCTION

THIS paper describes and illustrates the ostracode species of San Antonio Bay and vicinity along the central Texas coast, and discusses the environmental distribution of the ostracodes.

The literature on Recent marine and lagoonal Ostracoda from North America is relatively scarce despite the widespread interest of oil company micropaleontologists in the Cenozoic microfaunas. Somewhat greater attention has been given by American biologists to the fresh-water ostracodes, and there are important papers by Sharpe, Herrick, Turner, Dobbin, Furtos, Tressler, Hoff and others on the fresh-water faunas. For living marine species, the older European publications of Brady and collaborators, G. O. Sars and G. W. Müller, have been most useful to American workers. The Cenozoic ostracode collection of H. V. Howe at Louisiana State University has been almost the only source of comparative material for American paleontologists. Howe and his students have done much to clear up problems of the generic position of the American Tertiary ostracode species.

The present investigation of Recent ostracodes from the Rockport area of the central Texas coast has been made under the auspices of A.P.I. Research Project 51, directed by F. P. Shepard. Although the writer's principal aim at the start was to determine the environmental relationships of the Ostracoda, the taxonomic work has occupied most of the effort. The Ostracoda from approximately 180 stations in San Antonio Bay, Matagorda Island and the nearby open Gulf above 10 fathoms depth are described herein. Principal emphasis is here placed on the shell structures but the appendages of some of the species are described where the preservation permitted. A


* A contribution to Research Project 51 of the American Petroleum Institute.

few of the described forms are from Mesquite Bay adjoining San Antonio Bay on the west.

The first part of the paper is devoted to a description of the ostracode biofacies. The latter term is used in preference to biotope on the assumption that the environmental conditions which now exist along this part of the Texas coast have generally prevailed for an important part of post-glacial time, so that the sedimentary deposits containing the biofacies are up to several feet thick (Shepard and Moore, 1955). The ostracode biofacies, therefore, represents a temporal succession of biotopes.

## COLLECTION AND PREPARATION OF SAMPLES

The samples from which the ostracodes were obtained were collected by field groups of the Scripps Institution of Oceanography. David G. Moore was in charge of the field collecting. The samples were collected in July and August, 1951. The locations of the collecting stations are shown in Text-figure 1. A small collection of living ostracode specimens was obtained by the Scripps party, accompanied by P. L. Engel, a student at the University of Minnesota in March, 1953.

The samples were taken by means of a Phleger sampler or, in very shallow water, by thrusting a 1½ inch plastic tube into the bottom sediment. The samples studied here represent the upper centimeter of the bottom sediment. Neutralized formalin was added to the plastic tube containing the sample, and the tubes were sent to Scripps Institution where portions for study of the microfossils were extracted.

In the Marine Foraminifera Laboratory of F. B. Phleger at Scripps Institution, the microfaunal fractions were wet-sieved to remove the clay and silt sizes. The Foraminifera were studied by F. L. Parker, F. B. Phleger and J. Pierson (1953). The washed samples were then sent to the University of Minnesota where the ostracodes were picked out. All the ostracodes were picked from most of the samples and a minimum of 200 specimens was picked from very rich samples. The number of specimens of each species at each locality was tabulated and the weight percentage of the sand-sized fraction of the sample calculated.

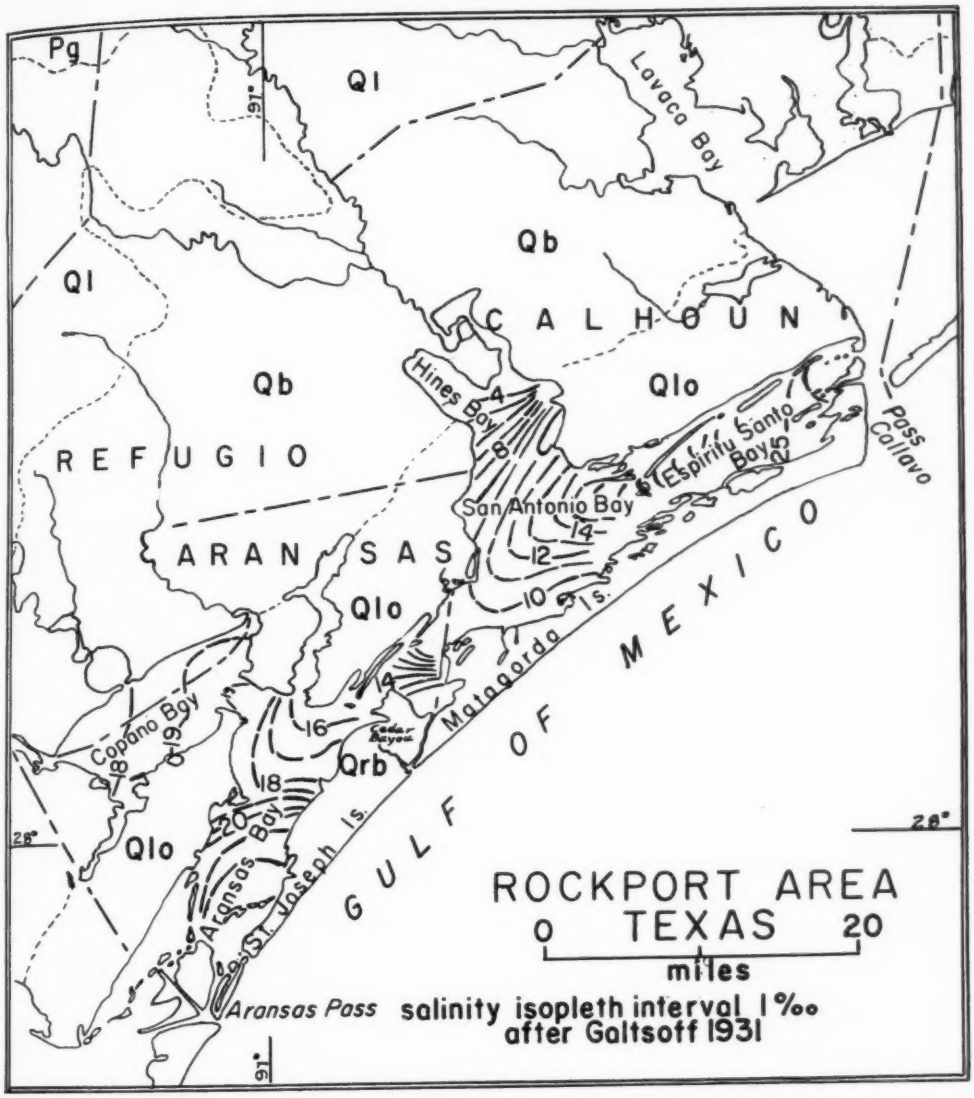
Representative specimens of each species were removed to separate slides and descriptions, photographs and drawings made. Most of the specimens photographed were first stained with methylene blue dye in ethyl alcohol and then coated with ammonium chloride.

The preserved specimens which were living when collected in March, 1953, were returned to the laboratory, washed free of silt and clay and stained with Rose Bengal solution, using the procedure of Walton (1952). The specimens which took the cytoplasm stain or which otherwise appeared to contain soft parts were separated from the sample and stored in formalin solution.

Specimens for dissection were placed on a slide, cleared with alcohol, immersed in glycerin and dissected. About a year elapsed between the time the specimens were collected and when they were removed from the formalin solution for dissection. In this time the shells had become considerably decalcified, despite the neutralization of the formalin, and as suggested by Hoff (1942), alcohol probably should have been used instead of formalin.

## DESCRIPTION OF SAN ANTONIO BAY AND VICINITY

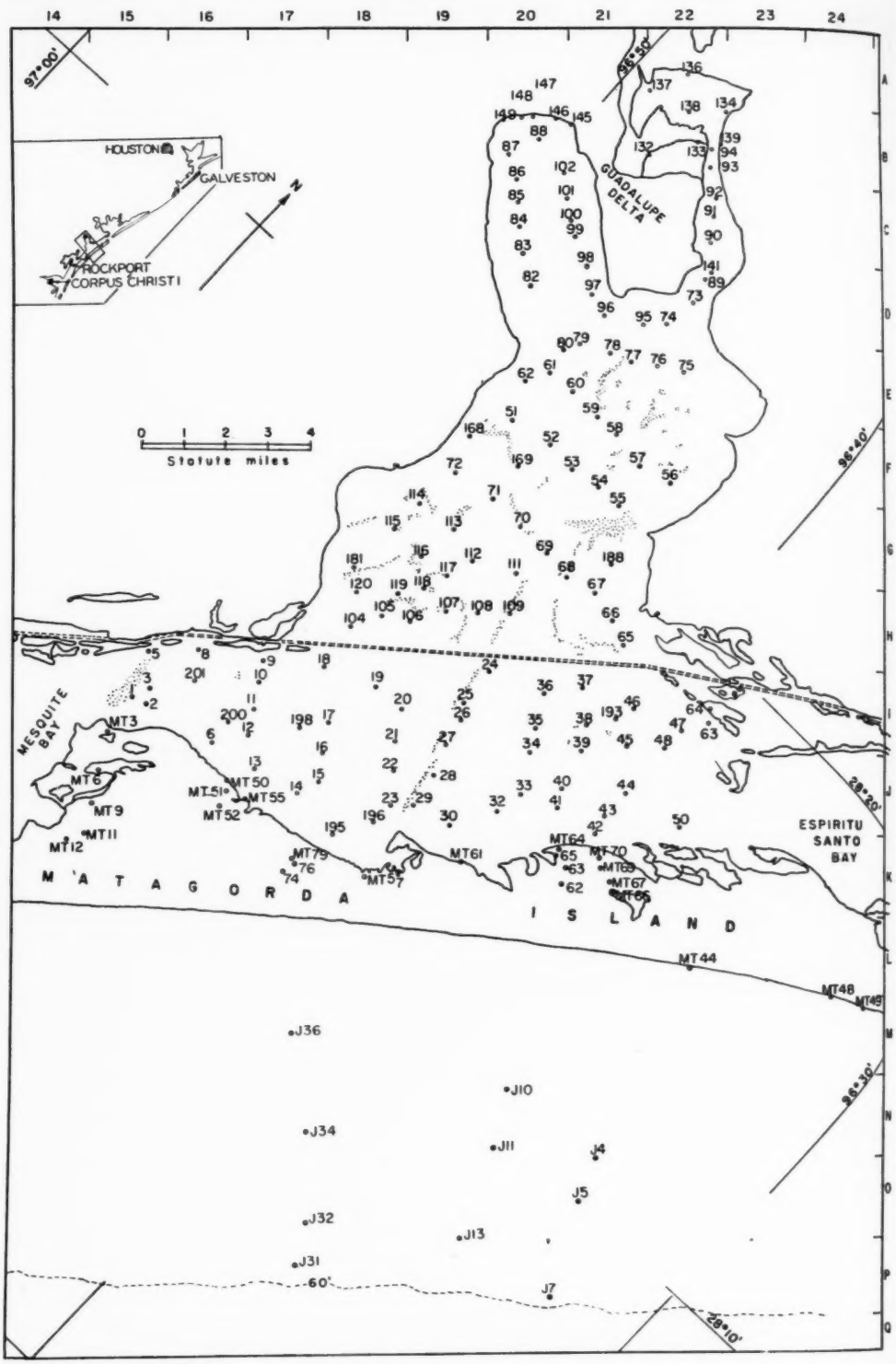
San Antonio Bay (Text-fig. 1) is located along the central part of the Texas coast in Calhoun, Refugio and Aransas counties, approximately within the area 28°15′ to 28°30′ N. Lat., and 96°35′ to 96°50′ W. Long., 60 miles northeast of Corpus Christi. The bay, which is 14 miles long and 5 to 14 miles wide, represents the eastern part of the Rockport area of the A.P.I. project. The bay is one of a chain of estuaries or former estuaries which includes Copano, Aransas, and Mesquite bays to the west and Espiritu Santo Bay to the east. The bays are separated from the Gulf of Mexico by Matagorda and St. Joseph islands, mature barrier beaches which are breached by only three passes in the Rockport area: the first is Aransas Pass, one-fourth mile wide and 25 feet deep at the southwest end of Aransas Bay; the second is Cedar Bayou connecting Mesquite Bay and the Gulf, 4 to 13 feet deep, with a sand bar at the mouth; and a third is an unnamed pass, generally dry, lying across Matagorda Island near Panther



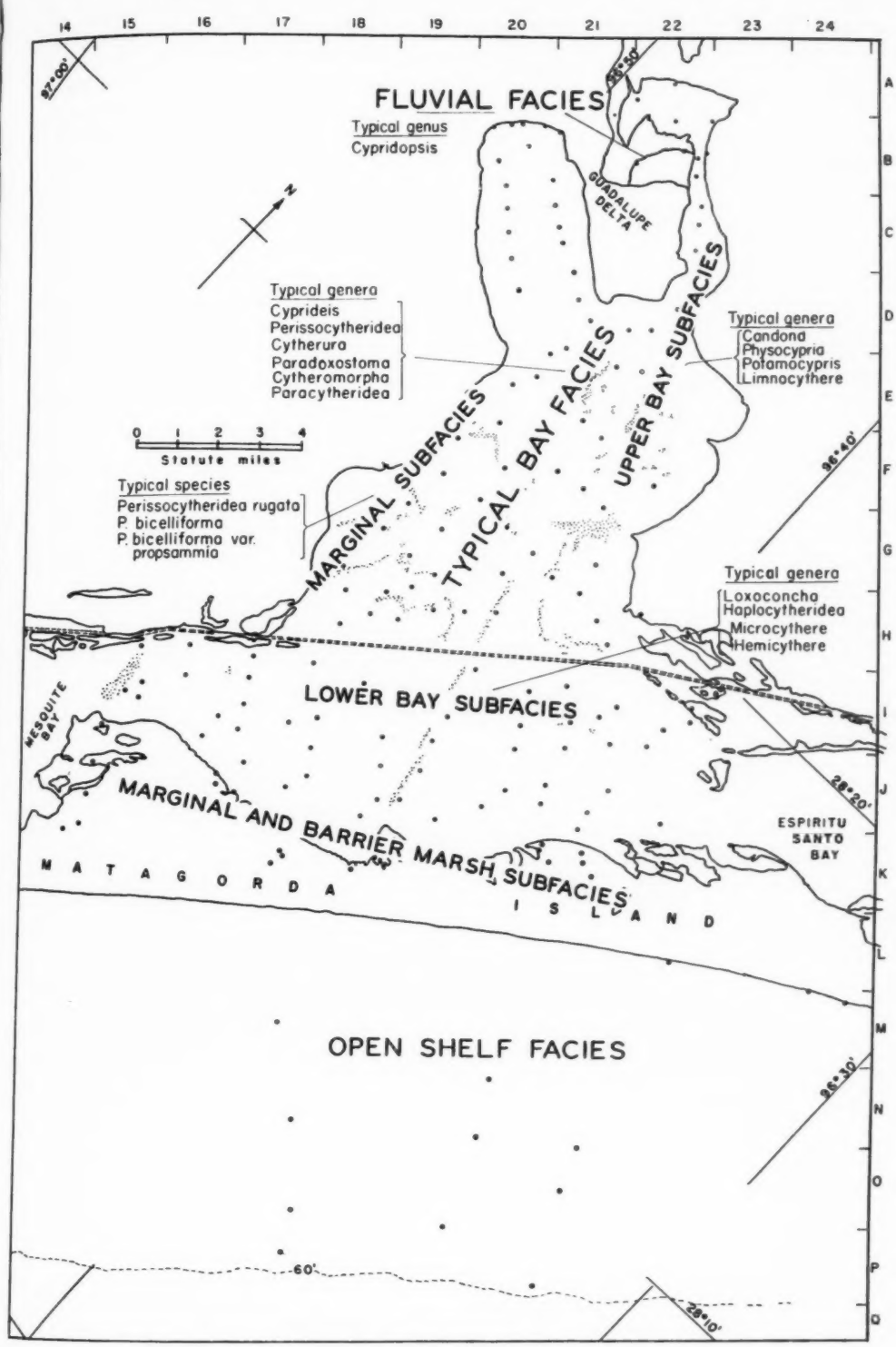

TEXT-FIG. *1*—Index map of Rockport area. Surface salinity values for midwinter 1926. Qrb, Recent offshore bar; Qlo, Live Oak mature offshore bar (Pleistocene); Qb, Beaumont clay; Ql, Lissie formation; Pg, Goliad formation.

Point. In addition, an important influx of Gulf water enters Espiritu Santo Bay by means of Pass Cavallo which connects Matagorda Bay with the Gulf. This Gulf water has an important effect on the surface salinity, as shown in Text-figure 1 (after Galtsoff, 1931).

San Antonio Bay is an estuary in its upper and a lagoon in its lower part. Guadalupe River has constructed a delta into the upper part of the bay, with the present distributaries flowing off the northeast side of the delta. The midbay sediments are soft, finely-sandy and silty clay, but marginally there are greater proportions of fine sand (Shepard and Moody, 1954). A network of oyster-shell banks ("reefs") has been constructed on the bay floor (Text-figs.




TEXT-FIG. 2—Map of San Antonio Bay and vicinity, showing locations of stations from which ostracodes were obtained in the Bay, Matagorda Island, and open Gulf of Mexico.




TEXT-FIG. 3—Map of San Antonio Bay and vicinity, showing principal ostracodal biofacies and subfacies, together with some of the genera or species typically found in each.

2 and 3) and there are numerous buried shell banks (Galtsoff, 1931; Puffer and Emerson, 1953; Norris, 1953).

According to Galtsoff (1931, p. 15) the bottom near the oyster banks is hard in some places, sticky in others. Shepard (Shepard and Moody, 1954, p. 4) has classified the estuarine part of the bay as a "bay near river" in which the sand-sized fraction of the bottom sediments includes small but important quantities of plant fibers, foraminifers, mollusk shells and ostracodes. The lower lagoonal part of the bay is more difficult to classify but is called a bay of intermediate type (Shepard, *op. cit.*, p. 3); toward the narrows at the east and west ends of the bay the amount of terrigenous sand increases as do mollusk shells. The barrier beach, Matagorda Island, has exerted a great influence upon the sedimentology and organisms of the bay.

Most of the run-off entering the bay is from Guadalupe River and it is believed that most of the water of the bay is supplied from the Gulf rather than from the river (Parker, Phleger and Pierson, 1953, p. 1). Evaporation exceeds precipitation in the area (Collier and Hedgpeth, 1950). The region drained by Guadalupe River consists mainly of the Quaternary Lissie sand and Beaumont clay formations; probably most of the sediment entering the bay from the river is from Beaumont clays.

Approximately the lower two-thirds of the bay is adjoined by old sand ridges which were called "Live Oak mature offshore bar" (Deussen, 1914) and have been placed in the Live Oak Bar formation (Weeks, 1945). These sands are an offshore bar facies of the Beaumont clay; they have yielded Pleistocene vertebrates. Much of the sand in San Antonio Bay may have been reworked from the Live Oak sands, and there may also be a mixing of the microfossils of the Live Oak with the Recent bay shells.

*Oceanographic data.*—As shown in Table 1, the bay is shallow, averaging about 5 feet in depth. The water is turbid most of the year as a result of the clay bottom, wave action, and perhaps in part plankton. There is marked seasonal variation in chlorinity, especially in the upper part of the bay, and there is in addition a large variation from year to year (Parker, Phleger and Pierson, 1953, pp. 1–2). A study should be made in the variation of living population of foraminifers and ostracodes with varying salinity in this area. The temperatures in Aransas and Copano bays range between 13°C. and 31°C. (Hedgpeth, 1951), but these may be too conservative by 5° to 10°C. (Parker, Phleger and Pierson, 1953, p. 3).

The bay water and the waters in the top few centimeters of the bay sediment are slightly alkaline, but near the river pH values slightly less than 7 were obtained. The oxidation-reduction potentials of the sediment vary from moderately oxidizing to mildly reducing, with the strongest oxidizing intensities in the lower bay. The lower bay is also marked by lower carbonate and lower total nitrogen and carbon content of the bottom sediment than the upper bay.

Two principal mass movements of water

TABLE 1.—PHYSICAL AND CHEMICAL DATA FOR SAN ANTONIO BAY AND VICINITY

| Biofacies | Subfacies | Bottom Materials | Chlorinity Range | Ave. depth (ft.) | pH | Eh[2] (mv) | Sediment | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Surface Total N (%) | Total C (%) | % Carbonate[3] Gasom. | % Carbonate[3] Org. |
| A. Typical Bay | A.1. Upper Bay | peat-clay, gyttja-clay, silt, sand | 1–16 °/₀₀ | 3 | 7.46 | + 56 | .17 | .84 | 23 | 2.5 |
| | A.2. Lower Bay | gyttja-silt-sand, shell-marl | 16.5–21 °/₀₀ | 5.5 | 7.35 | +202 | .07 | .49 | 4.1 | 3.1 |
| | A.3. Marginal | sand, silt, clay | 15–20 °/₀₀ | 5 | 7.5 | +181 | .06 | .46 | 4.7 | 6.7 |
| B. Fluvial | | peat-clay, clay silt, very fine sand | 1 °/₀₀[1] | 2.5 | 6.6 | +157 | .41 | 1.61 | 31? | ? |
| C. Open Gulf | | silt, sand | 20 °/₀₀ | 60 | 7.4 | +120 | .05 | .37 | 3.1 | 2.5 |

[1] Layering observed in February, 1952, with water of 7 °/₀₀ chl. underlying nearly fresh water.
[2] To refer the tabulated Eh values to the potential of the standard hydrogen electrode, add 245 mv.
[3] The carbonate content of the −200 mesh fraction of the sediments is referred to as "gasometric," while that of the coarser fraction, including fragments of macrofossils, foraminifers, ostracodes, etc. is "organic."

occur in the bay. Fluvial run-off results in a movement of water from the upper to the lower bay, then west into Mesquite Bay where it in part escapes to the Gulf through Cedar Bayou and in part moves into Aransas Bay. Movement to the east is prevented by a second water mass moving into Espiritu Santo Bay from an open Gulf source (Pass Callavo) farther east. The fundamental chlorinity difference between these two water masses combines with seasonal variation in water chemistry and food sources to produce several facies variations in the ostracodes of San Antonio Bay. Such facies variations have been determined to occur also among the Foraminifera (Parker, Phleger and Pierson, 1953) as discussed below.

## OSTRACODE BIOFACIES IN SAN ANTONIO BAY AND VICINITY

The ostracode biofacies and subfacies that have been recognized in the Rockport area are given below:

| | |
|---|---|
| River and prodelta facies | River subfacies |
| | Prodelta subfacies |
| Bay facies | Midbay subfacies |
| | Marginal subfacies |
| | Lower bay subfacies |
| Open gulf facies | Nearshore subfacies |
| | Offshore subfacies |

*Ostracode biofacies in San Antonio Bay.*—The ostracodes of San Antonio Bay form an assemblage that appears to be typical of a shallow bay fed by a river and with a restricted connection to the open sea. There is a bay facies characterized by the ostracode genera *Cyprideis*, *Perissocytheridea*, *Paracytheridea*, *Cytherura*, *Cytheromorpha* and *Paradoxostoma*. The lower bay, nearer to the normal marine influence, has species of these genera and also those of *Haplocytheridea*, *Hemicythere*, *Loxoconcha* and *Microcythere*. The marginal, sandier parts of the bay floor and some of the marshy lakes of Matagorda Island have a few restricted species of *Perissocytheridea* in addition to others found throughout the bay. Three subfacies of the bay are therefore recognized as follows:

Midbay subfacies

*Limnocythere sanctipatricii* Brady and Robertson (most abundant in upper bay)
*Cyprideis torosa* Jones
*Cyprideis littoralis* Brady
*Cyprideis lockетti* (Stephenson)
*Paracytheridea troglodyta*, n. sp.
*Perissocytheridea brachyforma*, n. sp. (also occurs in several of the Matagorda Island samples and rarely in the open Gulf)
*Cytherura elongata* Edwards (also from Matagorda Island lakes and marshes)
*Cytherura rara* Müller (also in open ocean)
*Cytherura johnsoni* Mincher (also from Matagorda Island and open Gulf)
*Cytherura forulata* Edwards
*Leptocythere paracastanea*, n. sp. (also open Gulf)
*Monoceratina?* sp.
*Paradoxostoma atrum* Müller
*Cytheromorpha curta* Edwards (most common in upper bay)

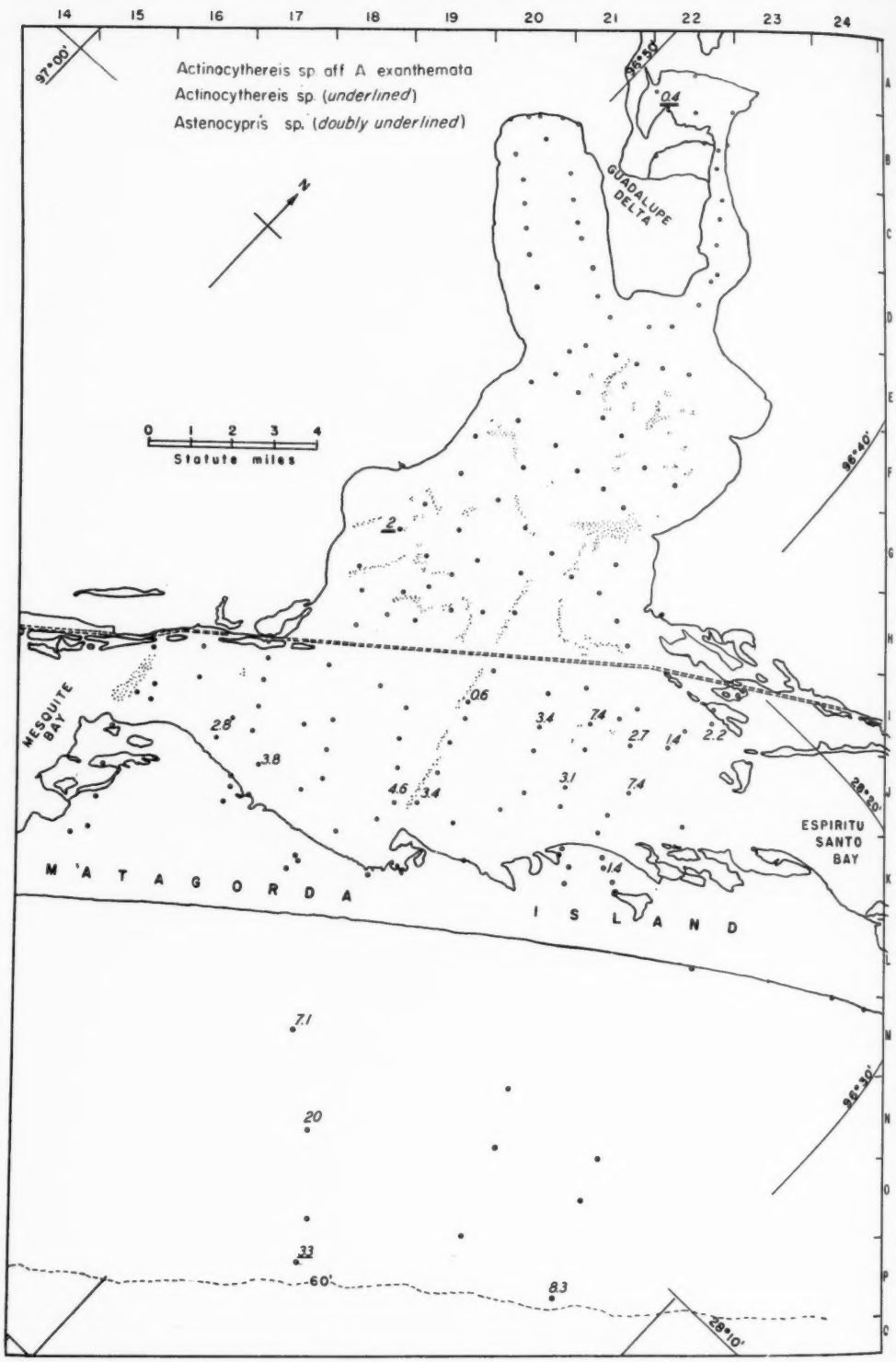
Marginal subfacies

*Perissocytheridea bicelliforma*, n. sp.
*Perissocytheridea rugata*, n. sp.
*Paradoxostoma ensiforme* Brady
(*Cytherura johnsoni* Mincher is relatively more abundant in the marginal parts of the bay than in the middle, where it is entirely absent at many stations).

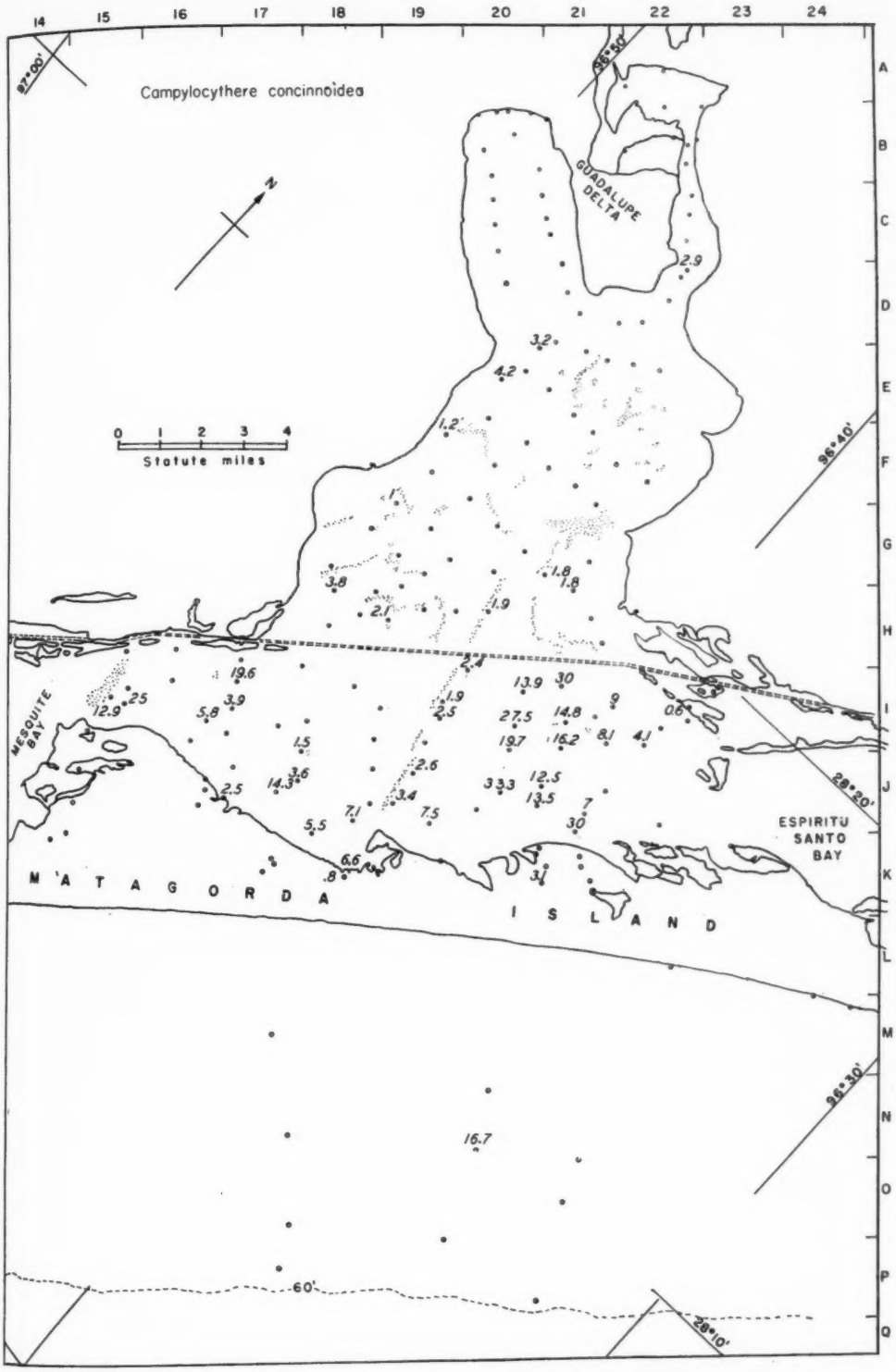
Lower bay subfacies

*Haplocytheridea bradyi* Stephenson (also rare in upper bay)
*Haplocytheridea bassleri* Stephenson
*Perissocytheridea brachyforma excavata*, n. subsp. (also rare from Matagorda Island and open Gulf)
*Paracytheridea vandenboldi* Puri
*Cytheromorpha* sp. (also Matagorda Island)
*Cytherura gibba* Müller
*Cytherura costata* Müller
*Loxoconcha matagordensis*, n. sp. (also from Matagorda Island)
*Campylocythere concinnoidea*, n. sp. (also rare in open Gulf and from Matagorda Island)
*Hemicytherideis* aff. *H. mayeri* Howe and Johnson
*Hemicytherideis* (also from Matagorda Island)
*Actinocythereis* aff. *A. exanthemata* (Ulrich and Bassler) (also is in open Gulf and is rare in upper bay and from Matagorda Island)
*Microcythere johnsoni* Mincher
*Hemicythere conradi* Howe and McGuirt (rare in upper bay and also from Matagorda Island)

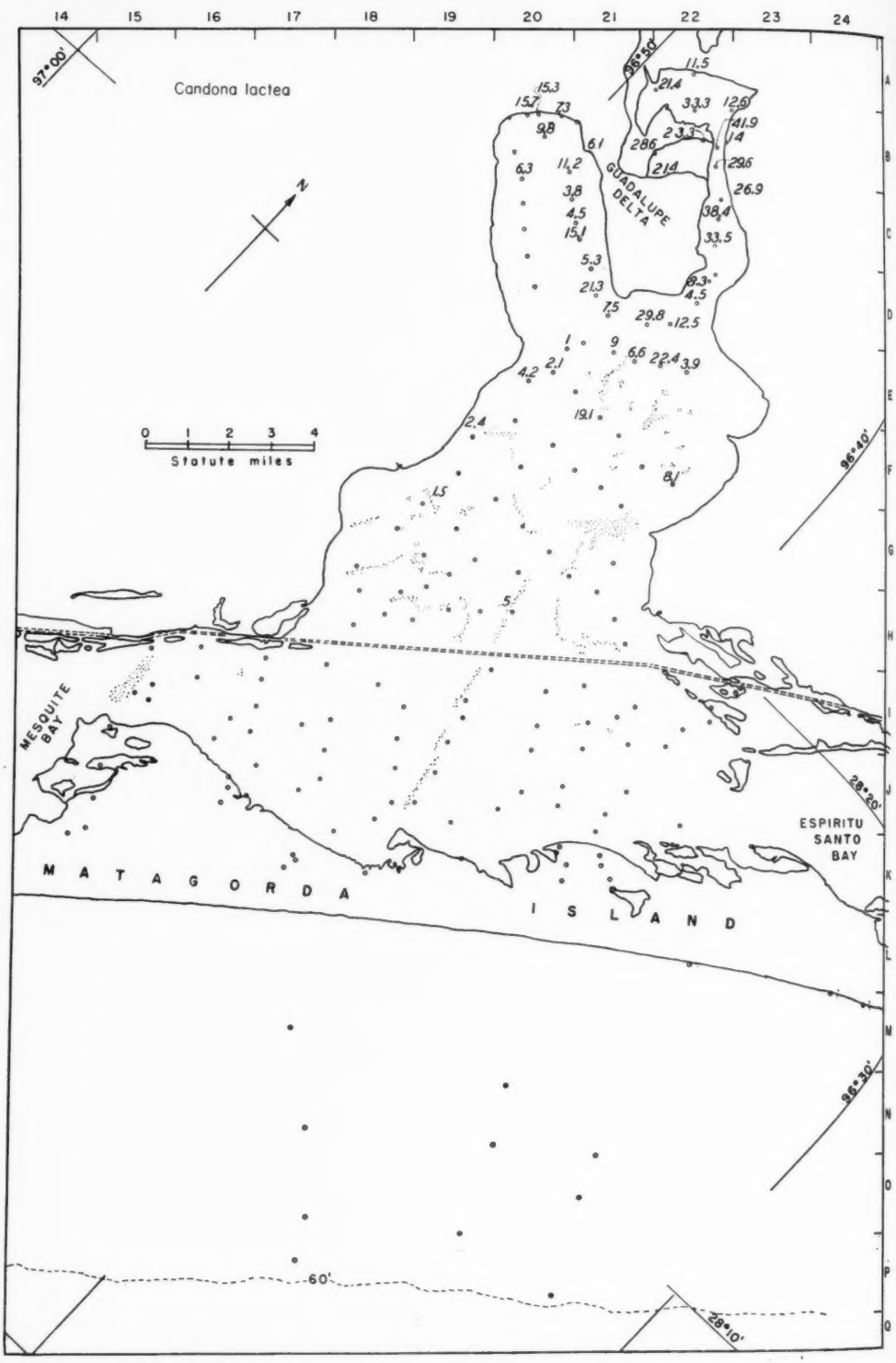
*Ostracode biofacies of Guadalupe River and prodelta area.*—The three stations along Guadalupe River distributaries yielded several genera of fresh-water ostracodes, but only *Cypridopsis* was restricted to the river. The prodelta area to the east and south of the river mouth yielded many *Candona*, *Physocypria*, *Potamocypris* and *Limnocythere* as well as species of the bay genera. "Mission Lake," north of the delta is very



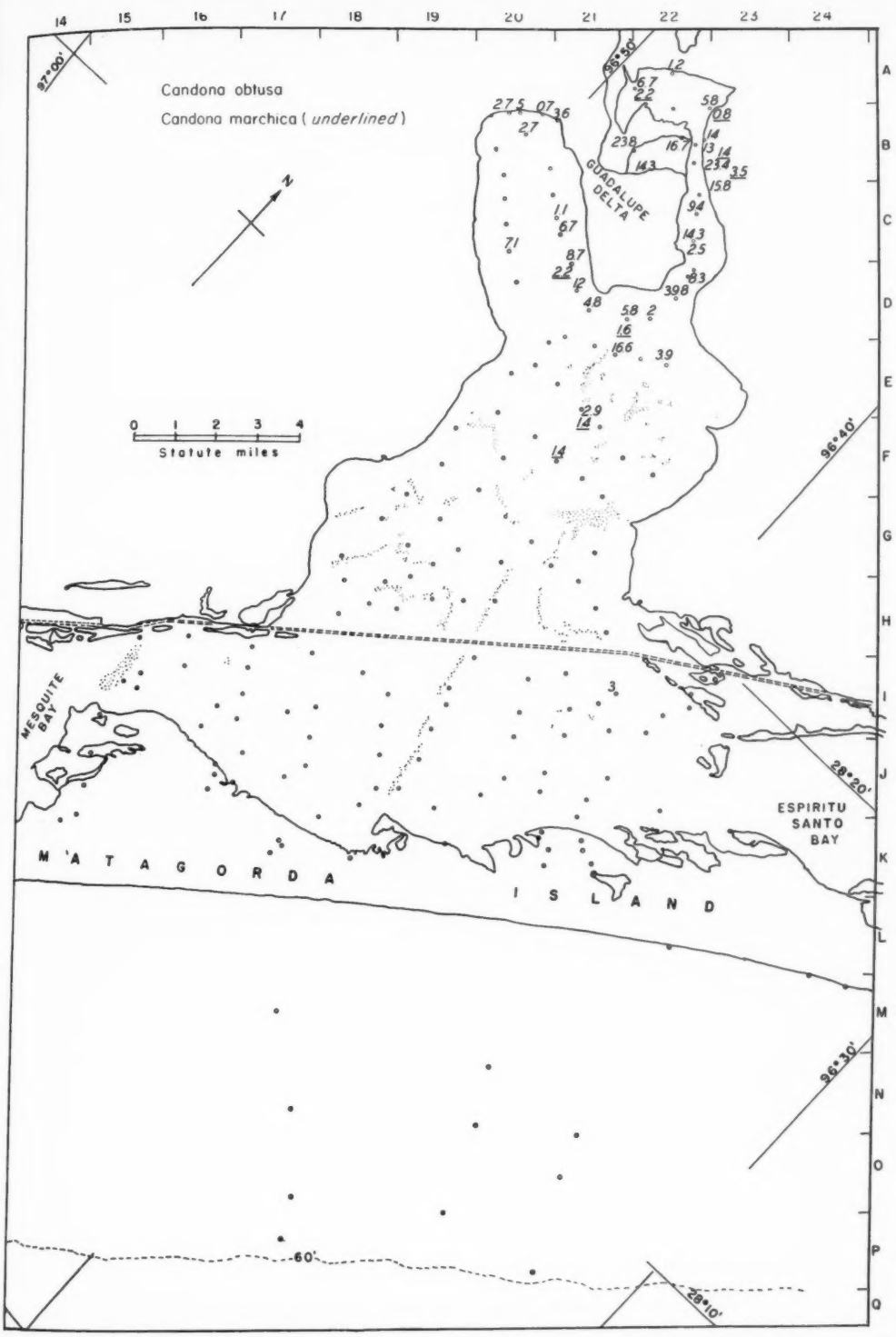

TEXT-FIG. 4—Distribution of *Actinocythereis* aff. *A. exanthemata* (Ulrich and Bassler), *Actinocythereis* sp., and *Astenocypris?* sp. in per cent of total population of ostracodes. Stippled areas represent oyster shell reefs.



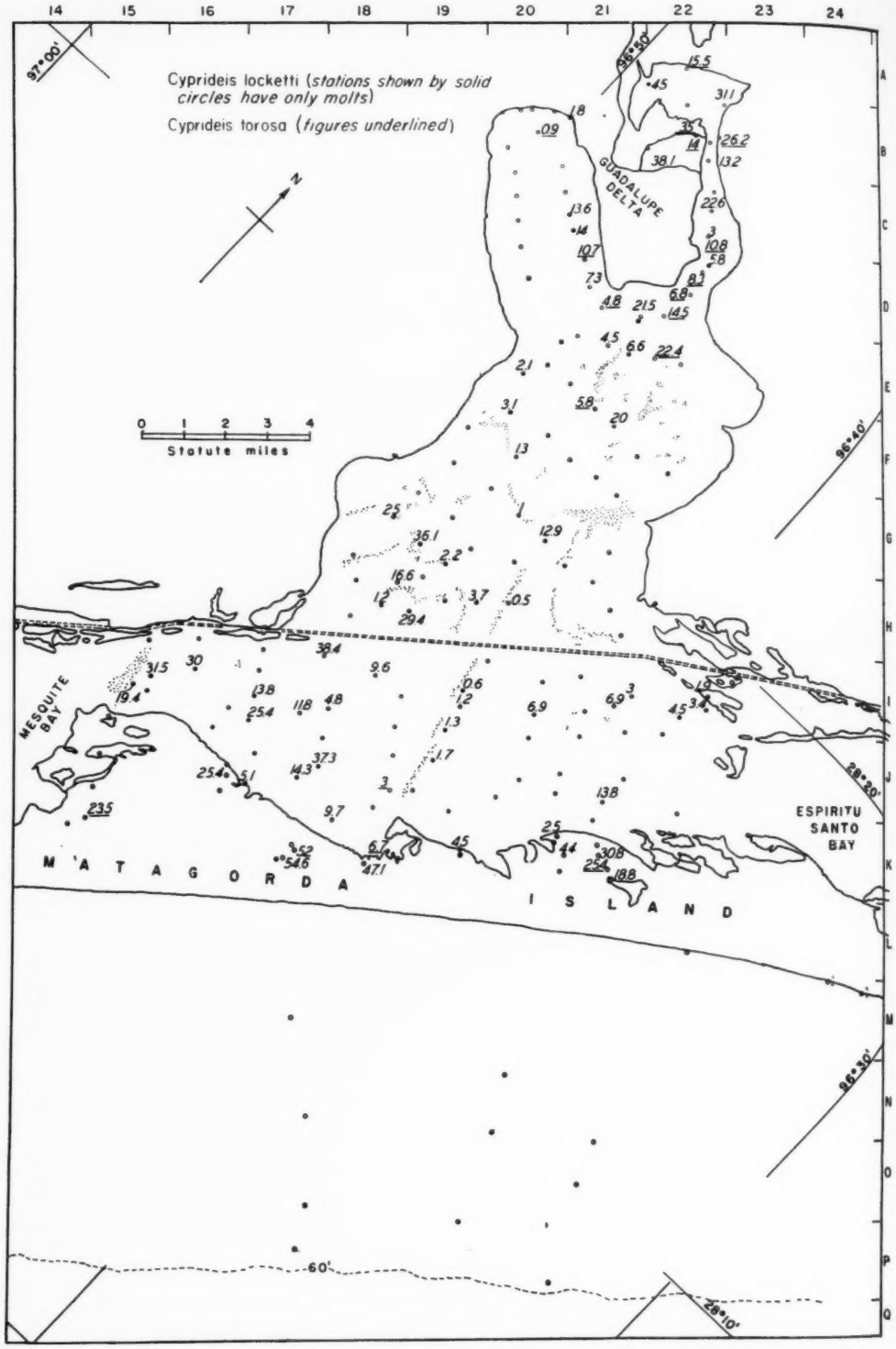

TEXT-FIG. 5—Distribution of *Camplyocythere concinnoidea* Swain, n. sp., in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



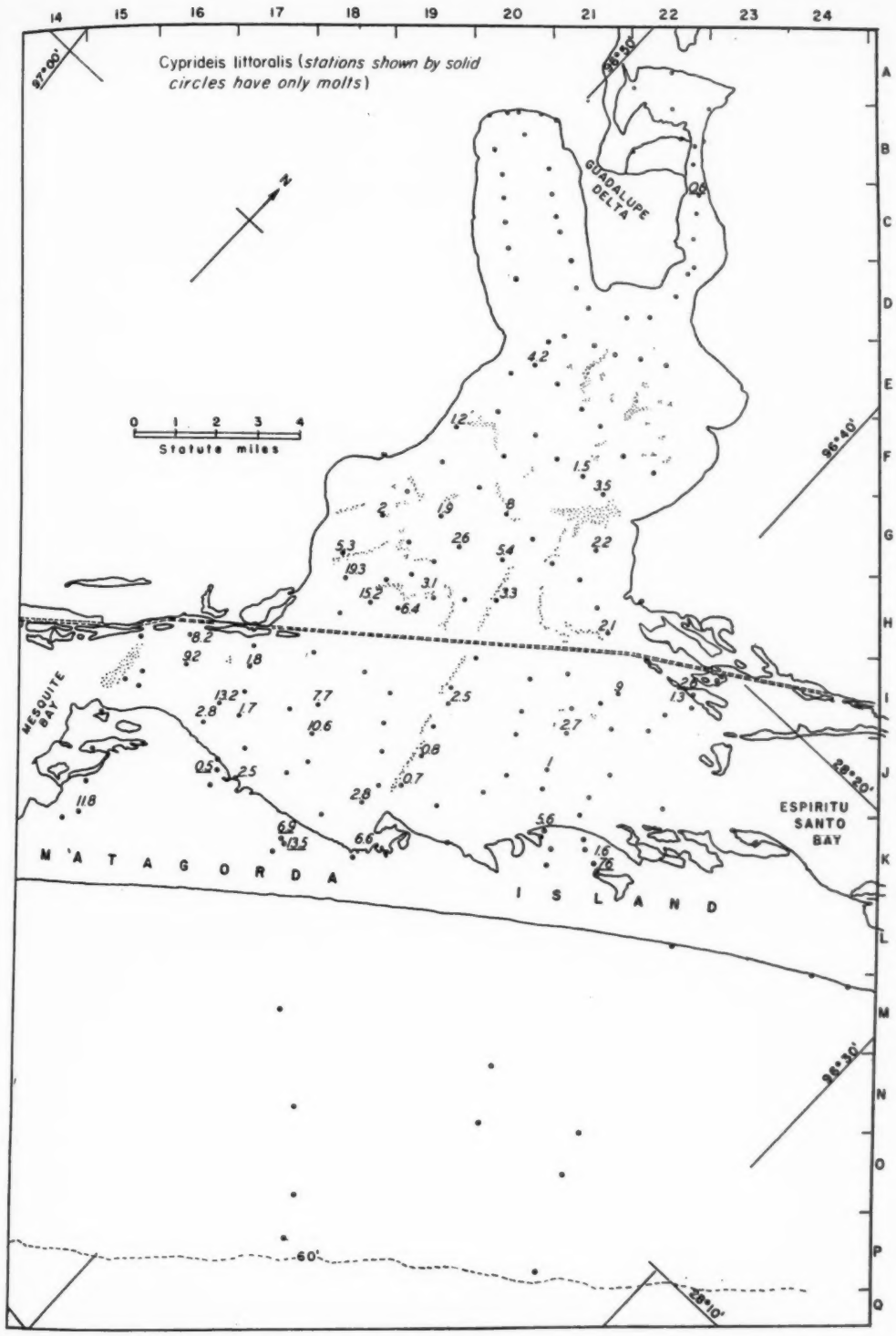

TEXT-FIG. *6a*—Distribution of *Candona lactea* Baird in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



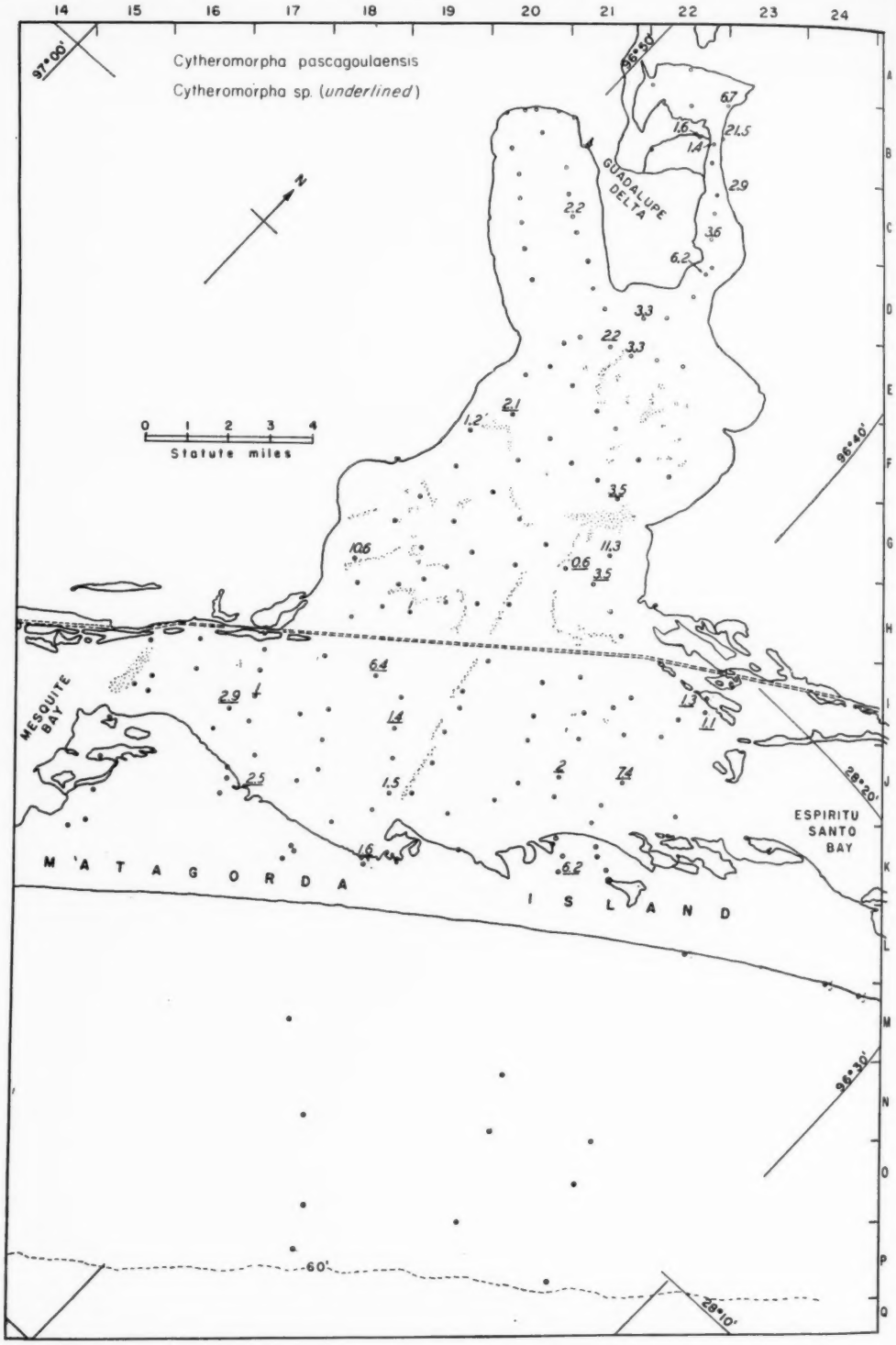

TEXT-FIG. *6b*—Distribution of *Candona obtusa* Bronstein and *Candona marchica* Hartwig in per cent of total ostracode population at each station. Stippled areas represent oyster shell reefs.


Cyprideis lockett (stations shown by solid circles have only molts)
Cyprideis torosa (figures underlined)
Statute miles
GUADALUPE DELTA
MESQUITE BAY
ESPIRITU SANTO BAY
M A T A G O R D A I S L A N D
60'

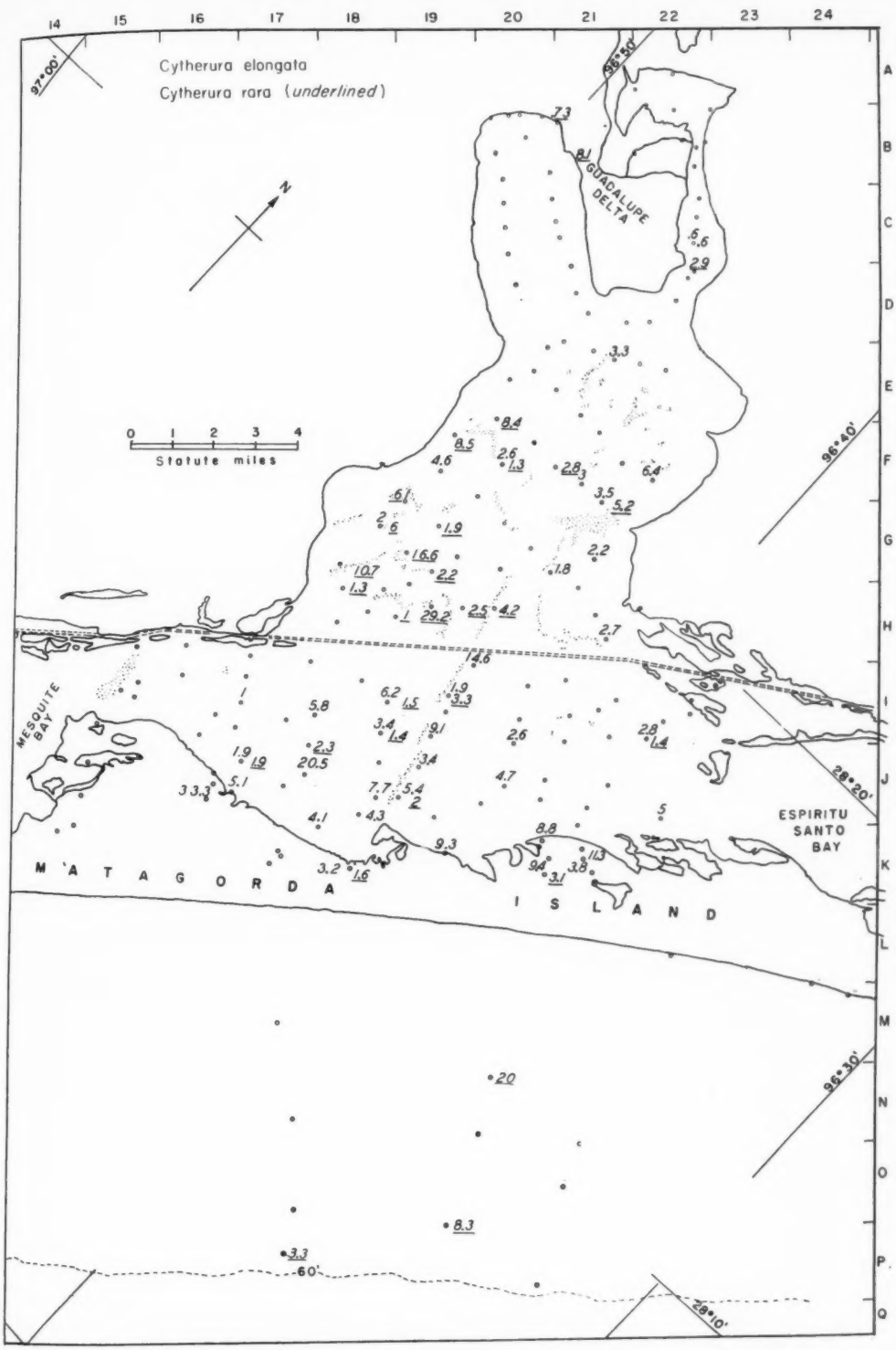
TEXT-FIG. 7—Distribution of *Cyprideis lockett* (Stephenson) and *Cyprideis torosa* (Jones) in per cent of total ostracode population. Stippled areas represent oyster reefs.



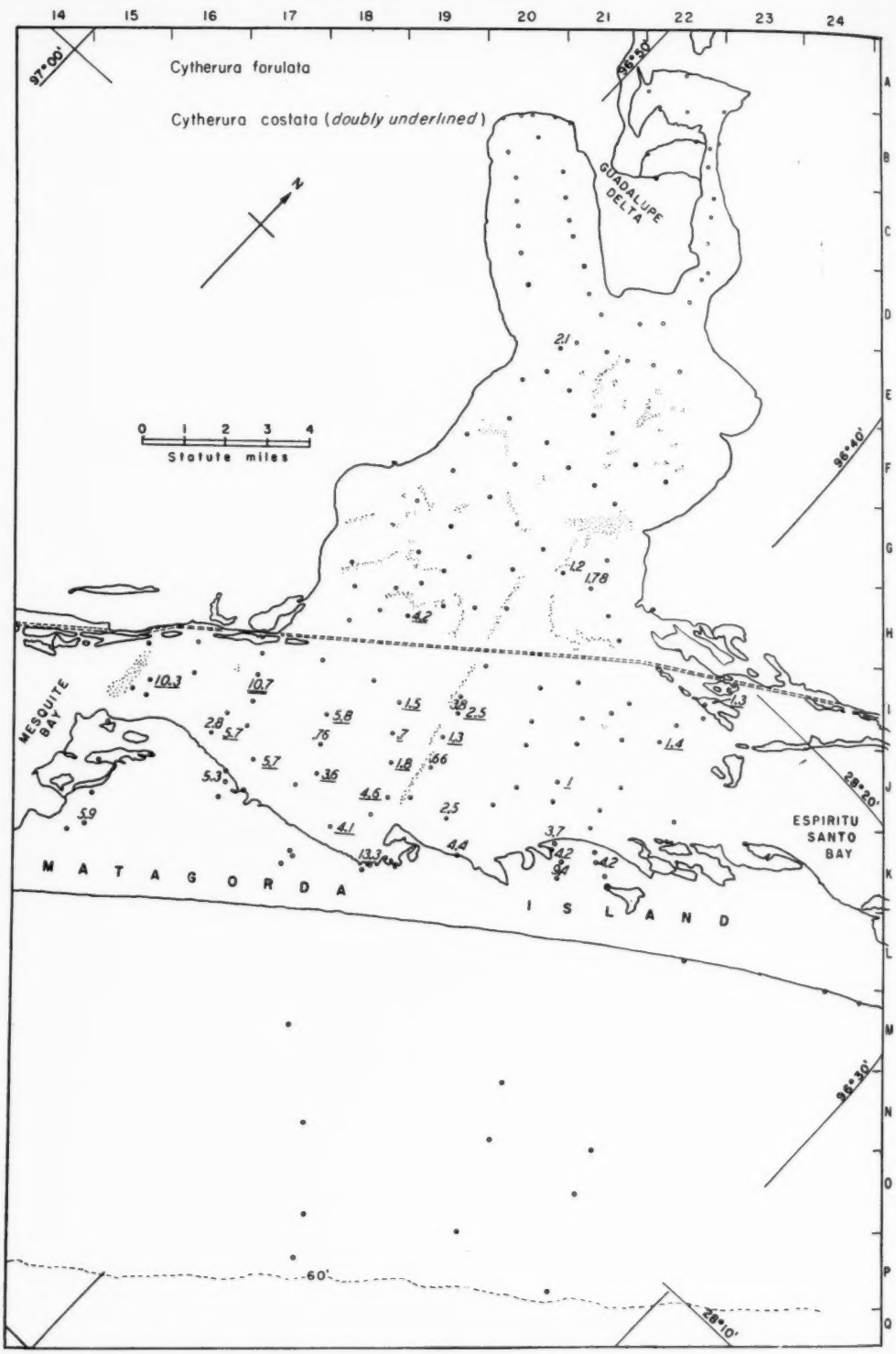

TEXT-FIG. 8—Distribution of *Cyprideis littoralis* Brady and *Cyprinotus salinus* (Brady) in per cent of total ostracode population—occurrences of the latter are underlined in the figure. Stippled areas represent oyster shell reefs.



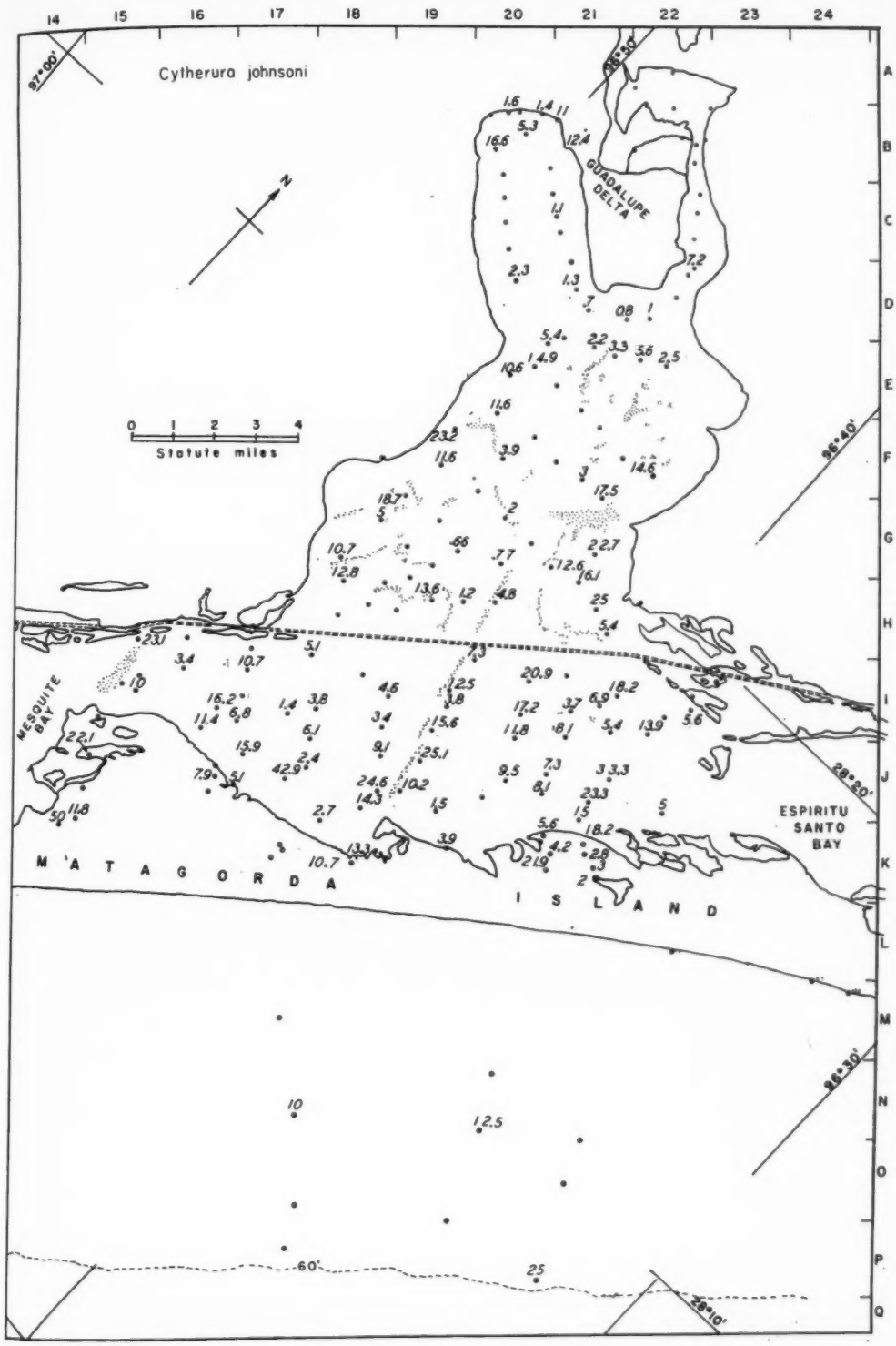

TEXT-FIG. 9—Distribution of *Cytheromorpha pascagoulaensis* Mincher and *Cytheromorpha* sp. in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



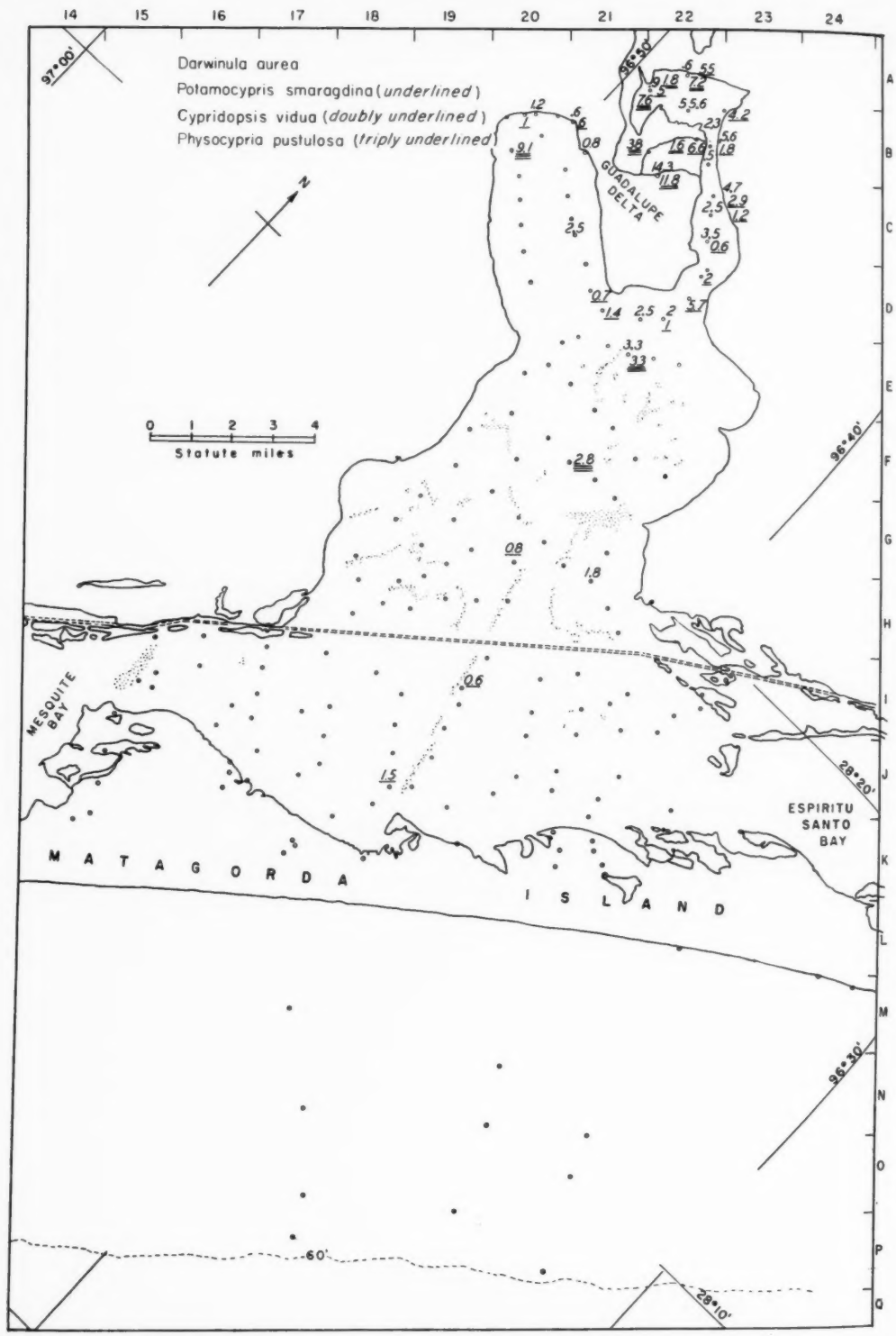

TEXT-FIG. *10*—Distribution of *Cytherura elongata* Edwards and *Cytherura rara* Müller in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



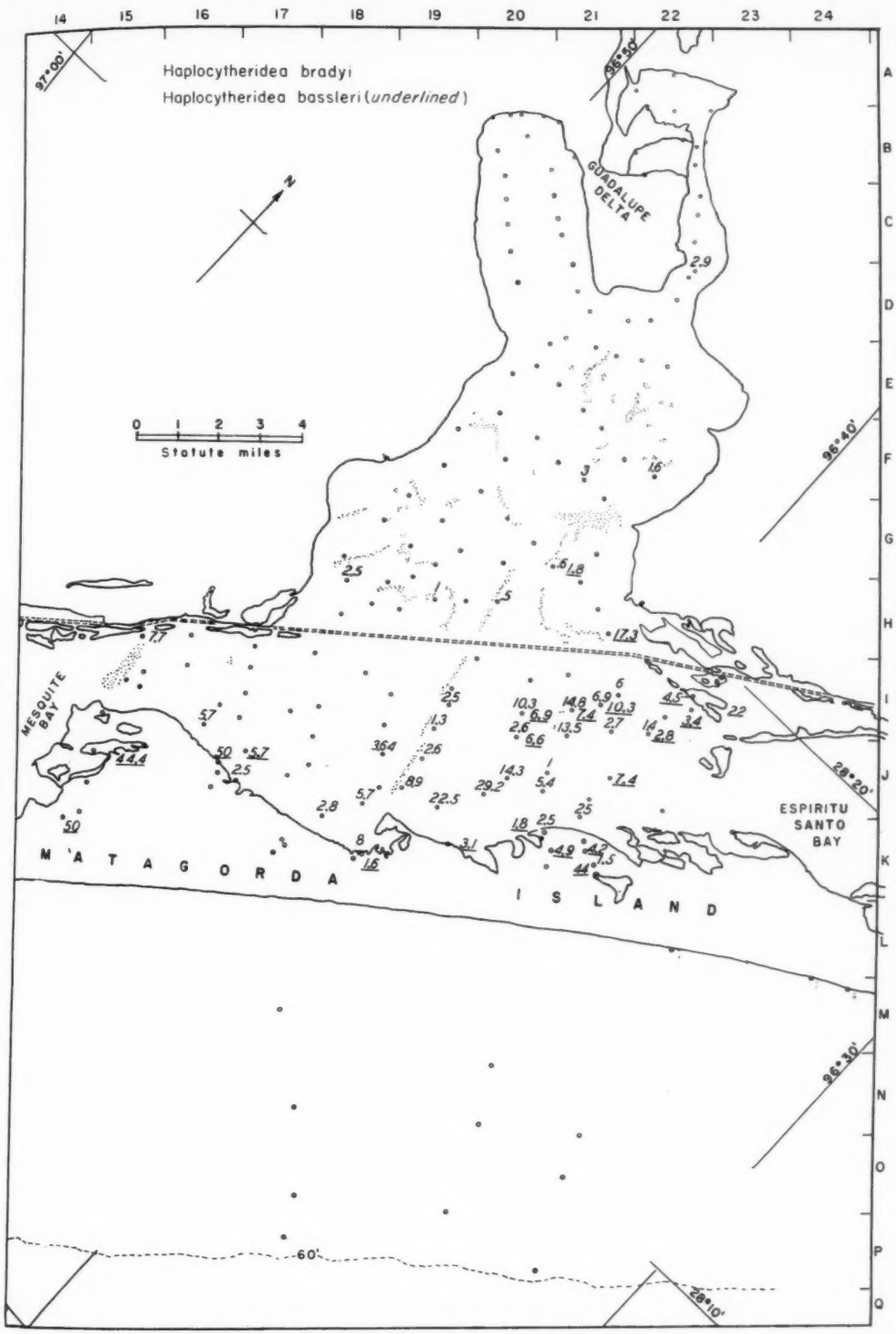

TEXT-FIG. *11*—Distribution of *Cytherura forulata* Edwards, *Cytherura radialirata* Swain, n. sp., and *Cytherura costata* Müller in per cent of total ostracode population. In the figure, occurrences of the second species are singly underlined. Stippled areas represent oyster shell reefs.



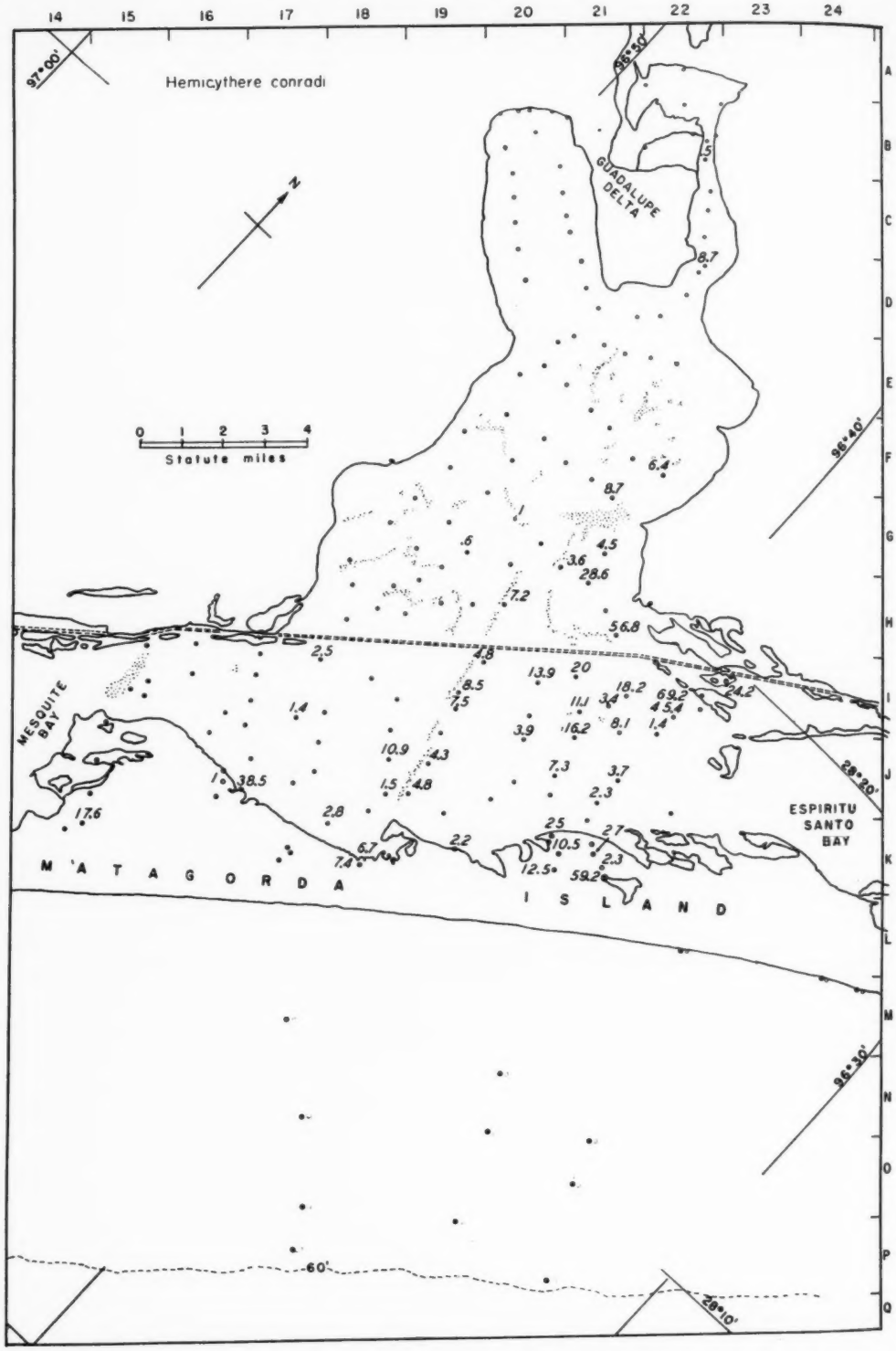

TEXT-FIG. *12*—Distribution of *Cytherura johnsoni* Mincher in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



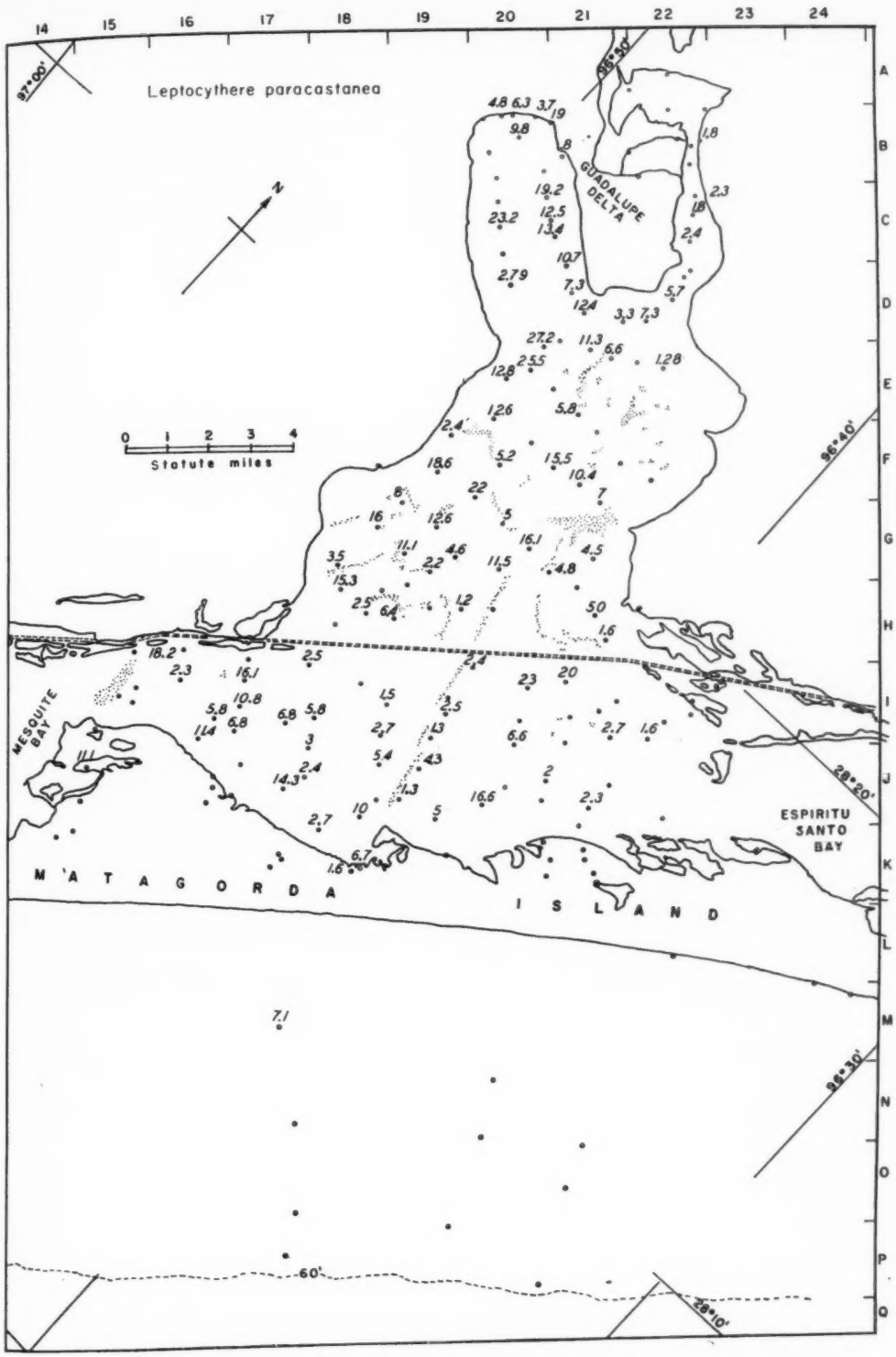

TEXT-FIG. *13*—Distribution of *Darwinula aurea* (Brady and Robertson), *Potamocypris smaragdina* (Vavra), *Cypridopsis vidua* (Müller) and *Physocypria pustulosa* (Sharpe) in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



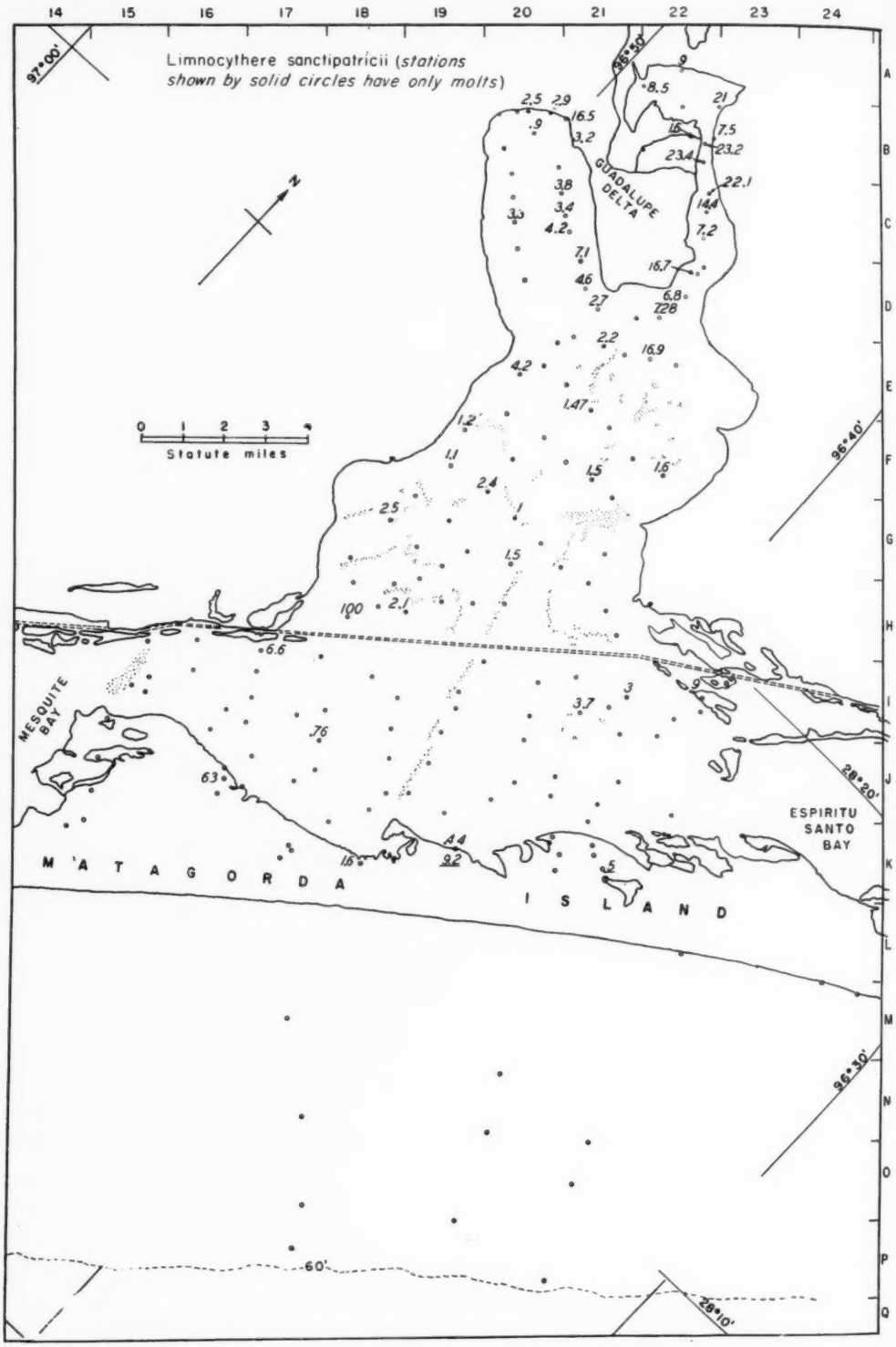

TEXT-FIG. *14*—Distribution of *Haplocytheridea bradyi* (Stephenson) and *Haplocytheridea bassleri* (van den Bold) in per cent of total ostracode population. Stippled areas represent oyster reefs.



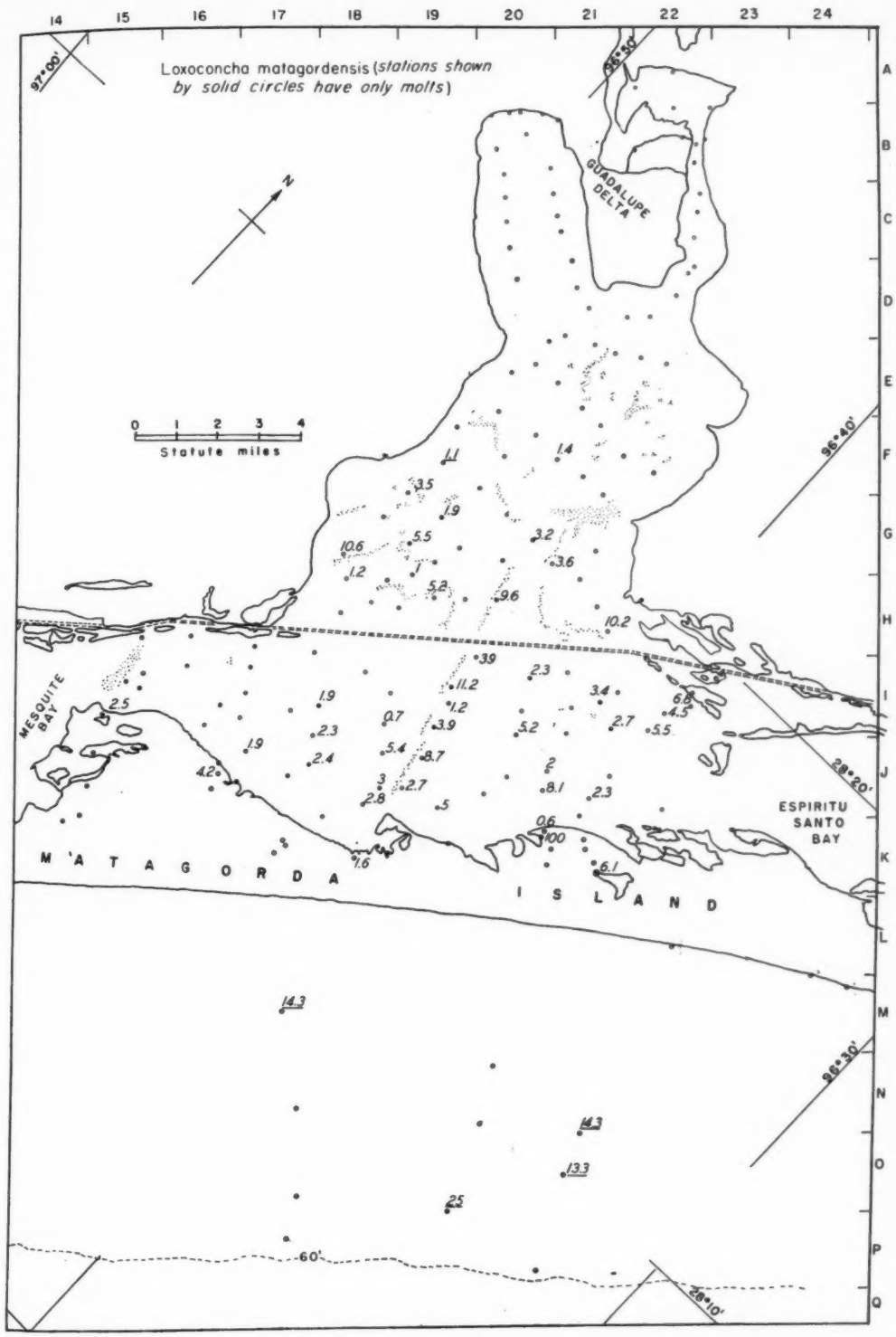

TEXT-FIG. *15*—Distribution of *Hemicythere conradi* Howe and McGuirt in per cent of total ostracode population. Stippled areas represent oyster reefs.



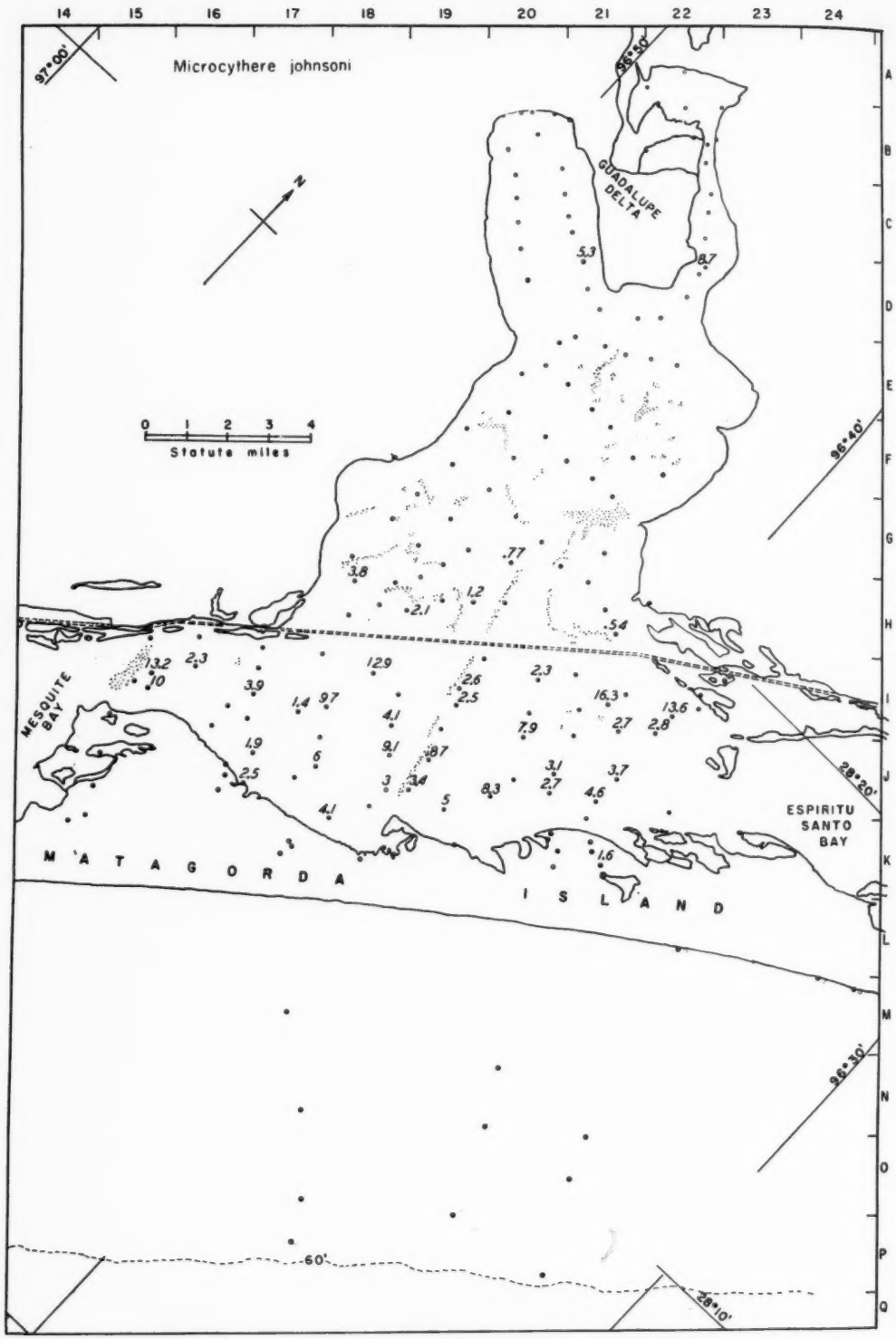

TEXT-FIG. *16*—Distribution of *Leptocythere paracastanea* Swain, n. sp., in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



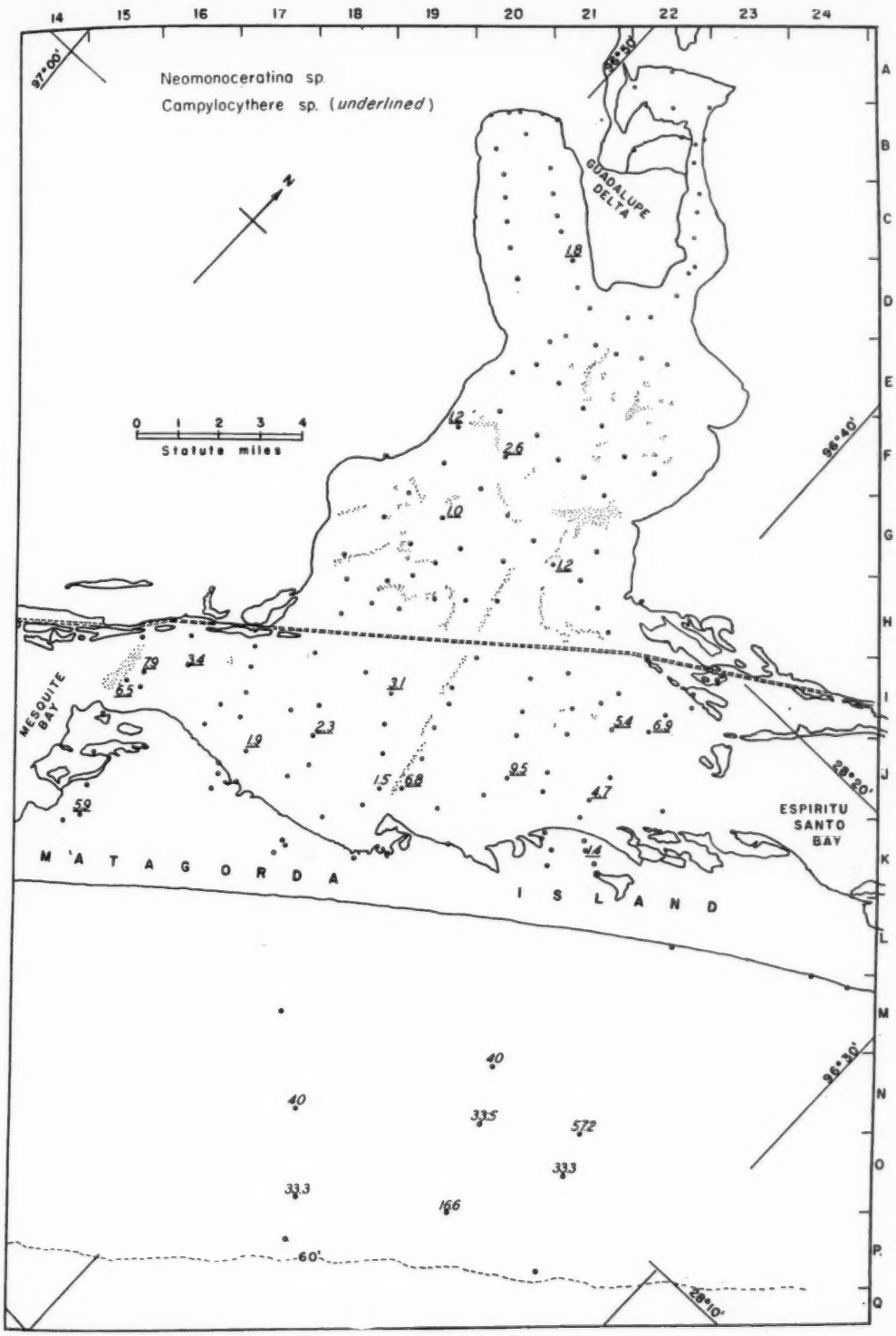

TEXT-FIG. *17*—Distribution of *Limnocythere sanctipatricii* Brady and Robertson in per cent o total ostracode population. Stippled areas represent oyster shell reefs.



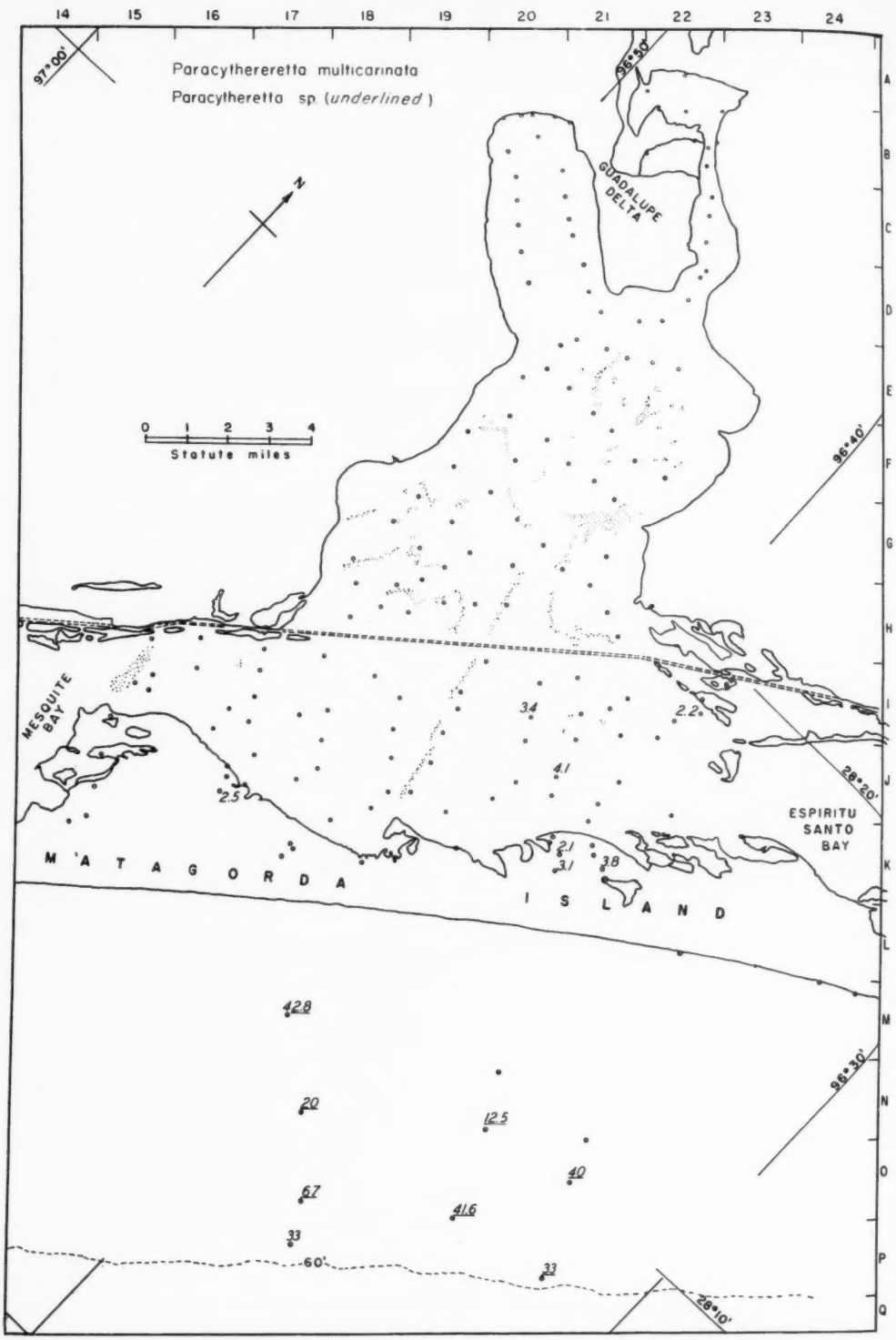

TEXT-FIG. *18*—Distribution of *Loxoconcha matagordensis* Swain, n. sp., and *Loxoconcha australis* Brady in per cent of total ostracode population—occurrences of the latter are underlined in the figure. Stippled areas represent oyster reefs.



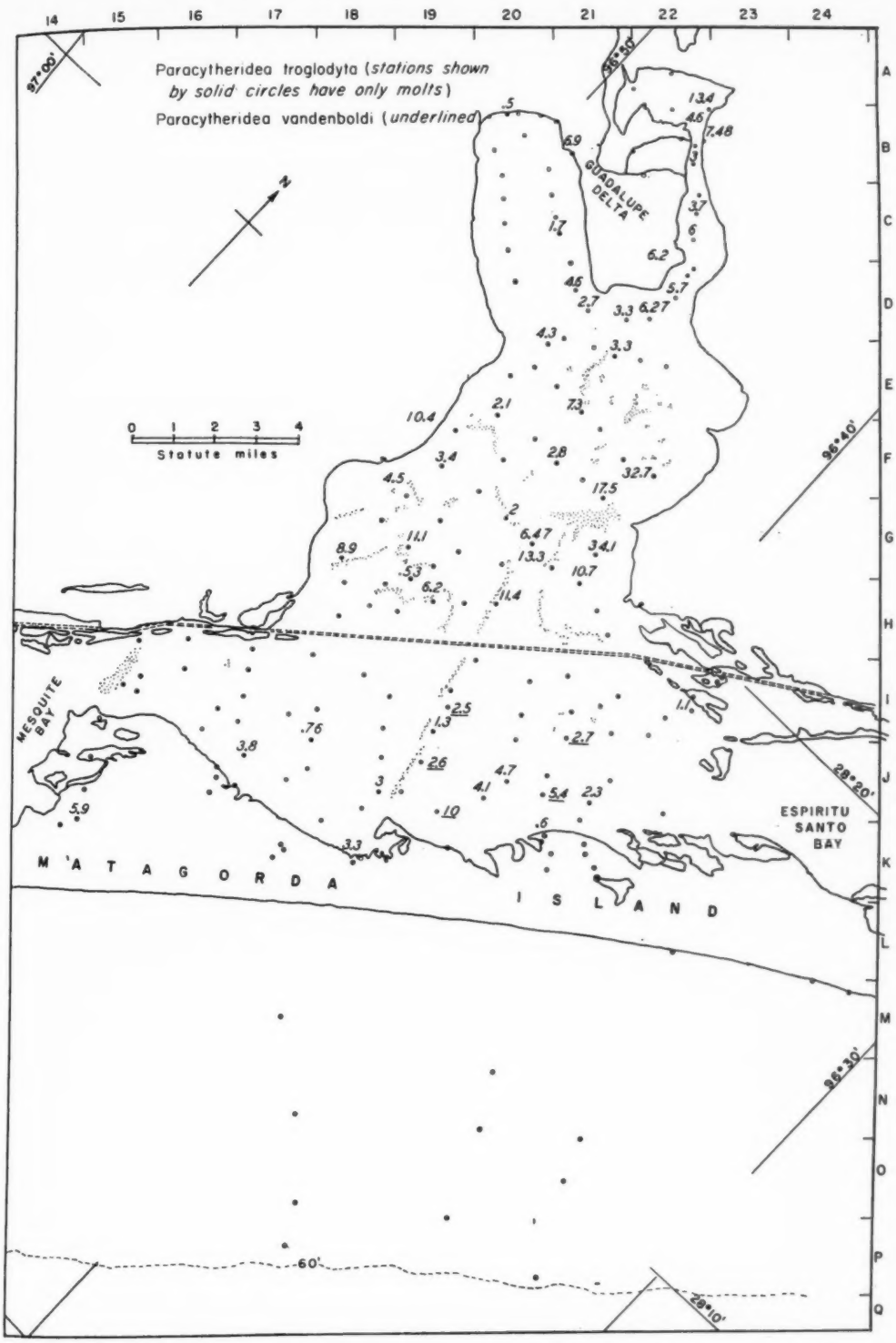

TEXT-FIG. *19*—Distribution of *Microcythere johnsoni* Mincher in per cent of total ostracode population. Stippled areas represent oyster reefs.



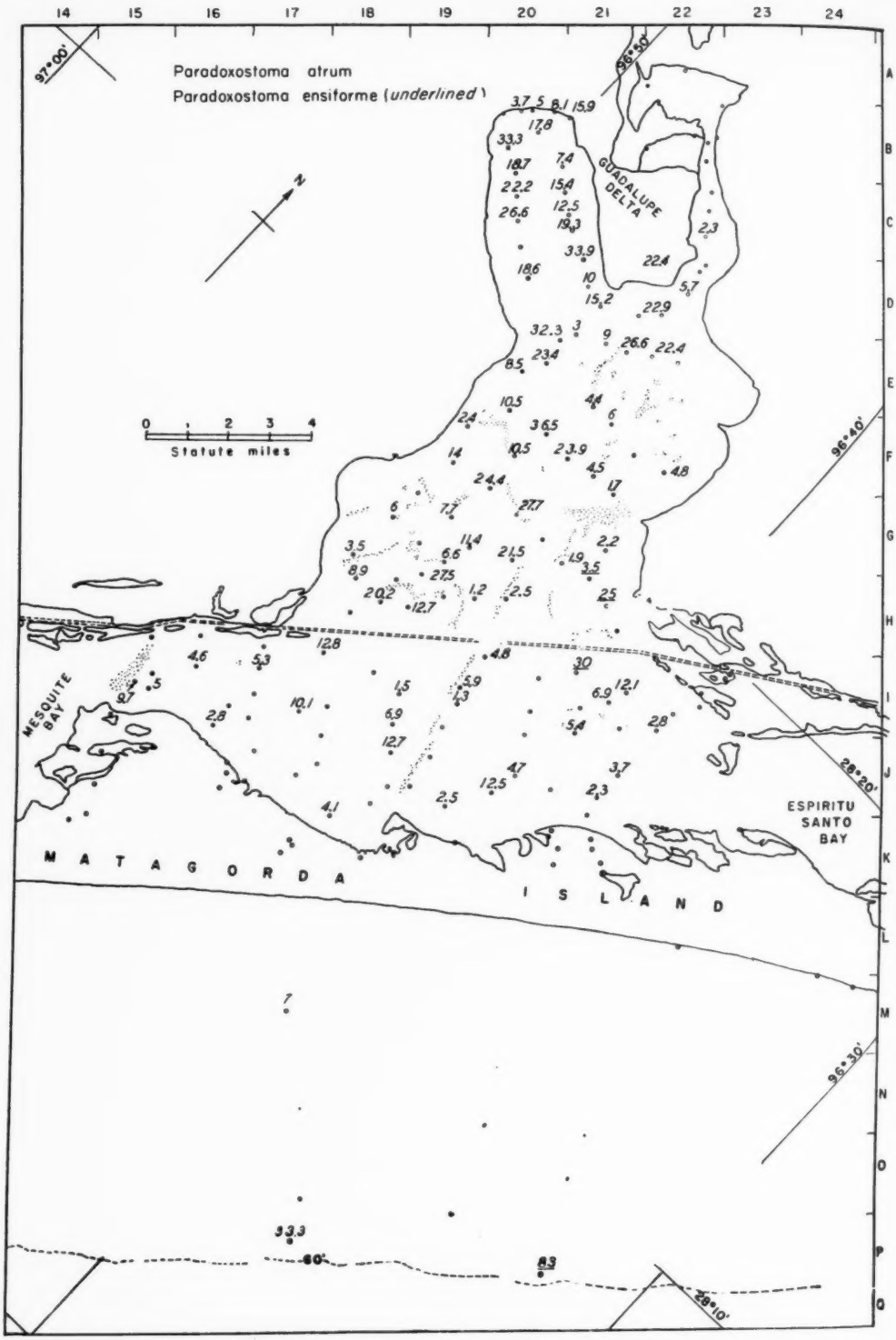

TEXT-FIG. 20—Distribution of *Neomonoceratina* sp. and *Campylocythere* sp. in per cent of total ostracode population. Stippled areas represent oyster reefs.



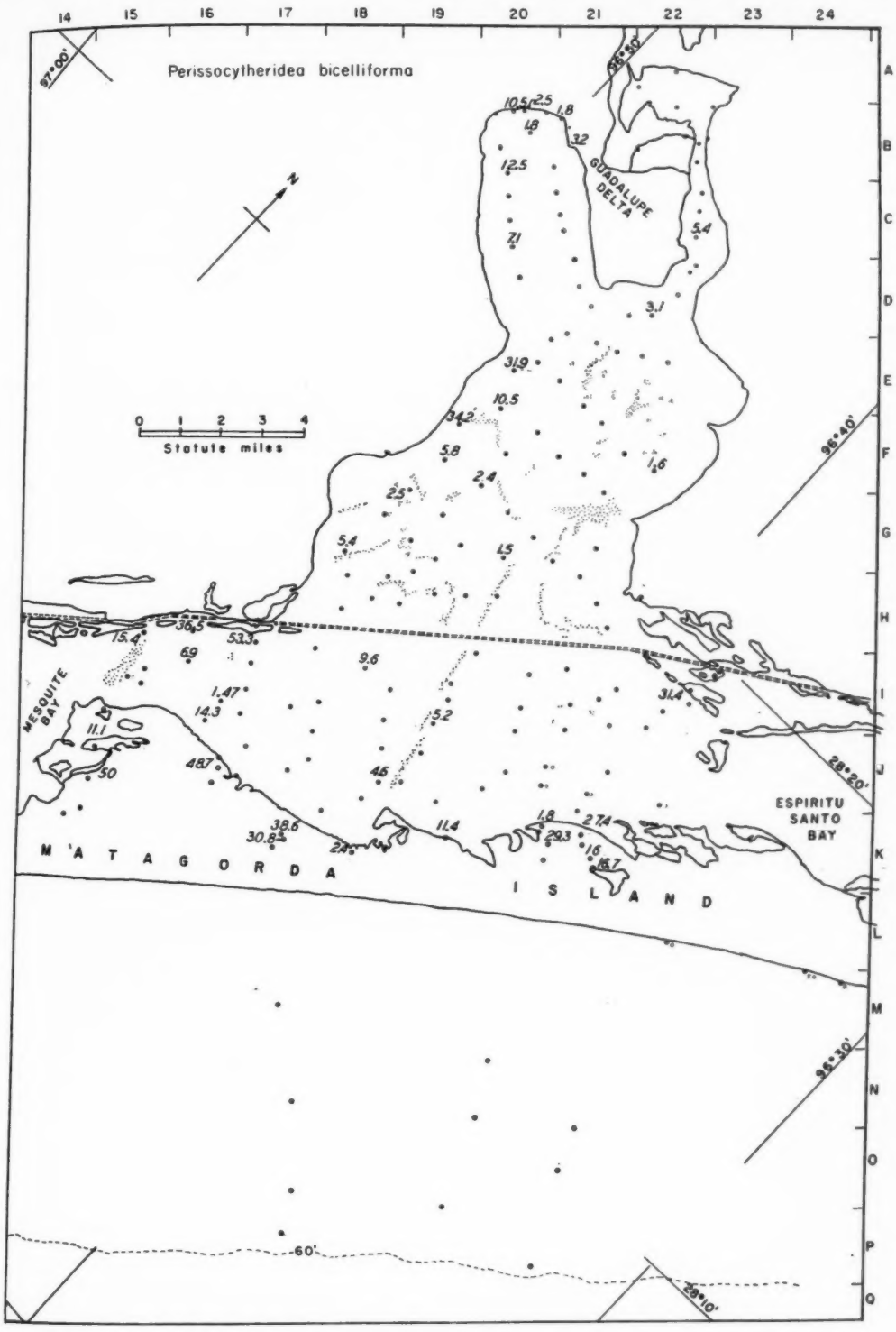

TEXT-FIG. *21*—Distribution of *Paracytheretta multicarinata* Swain, n. sp., and *Paracytheretta?* sp. in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



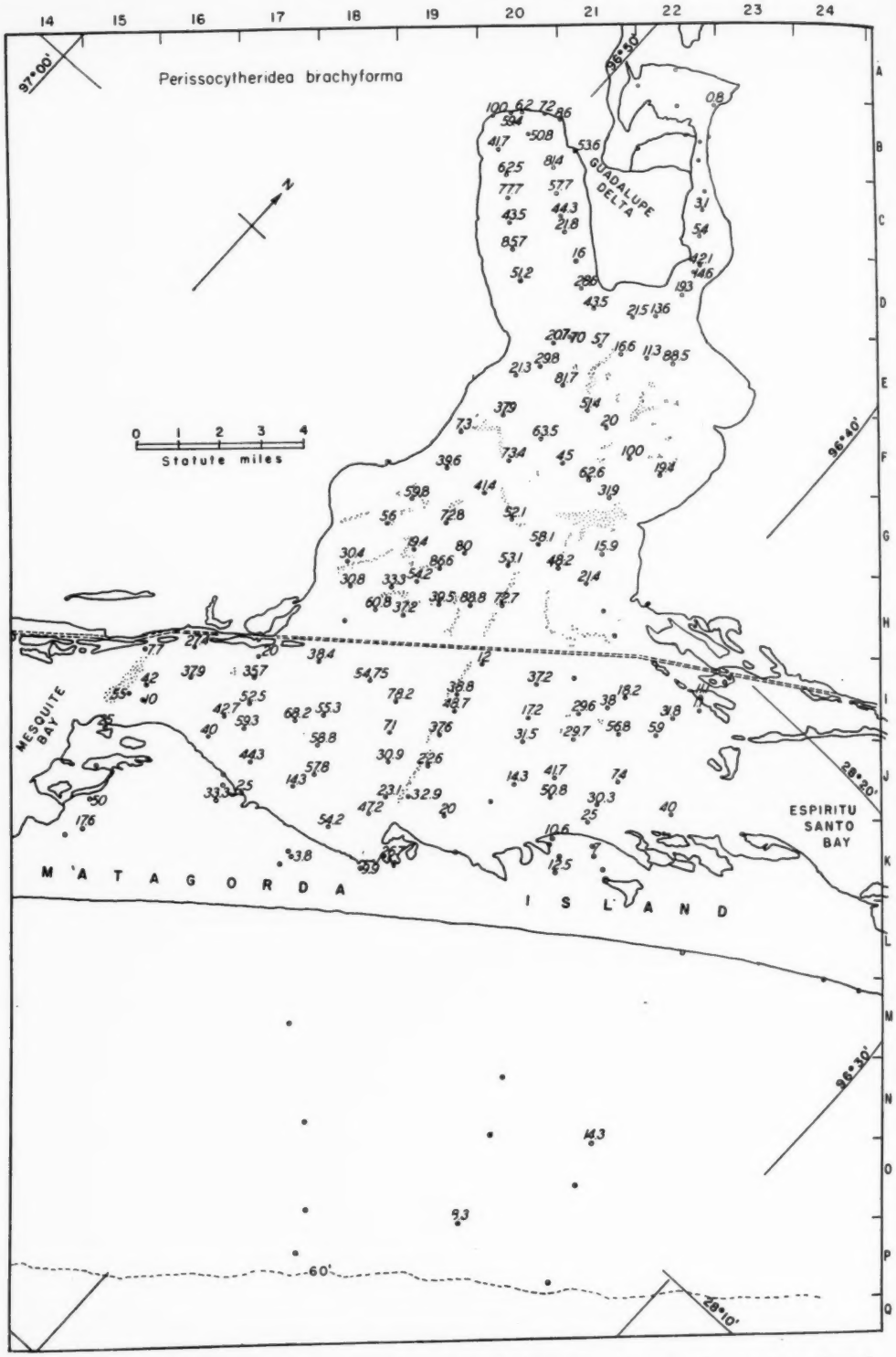

TEXT-FIG. 22—Distribution of *Paracytheridea troglodyta* Swain, n. sp., and *Paracytheridea vandenboldi* Puri in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



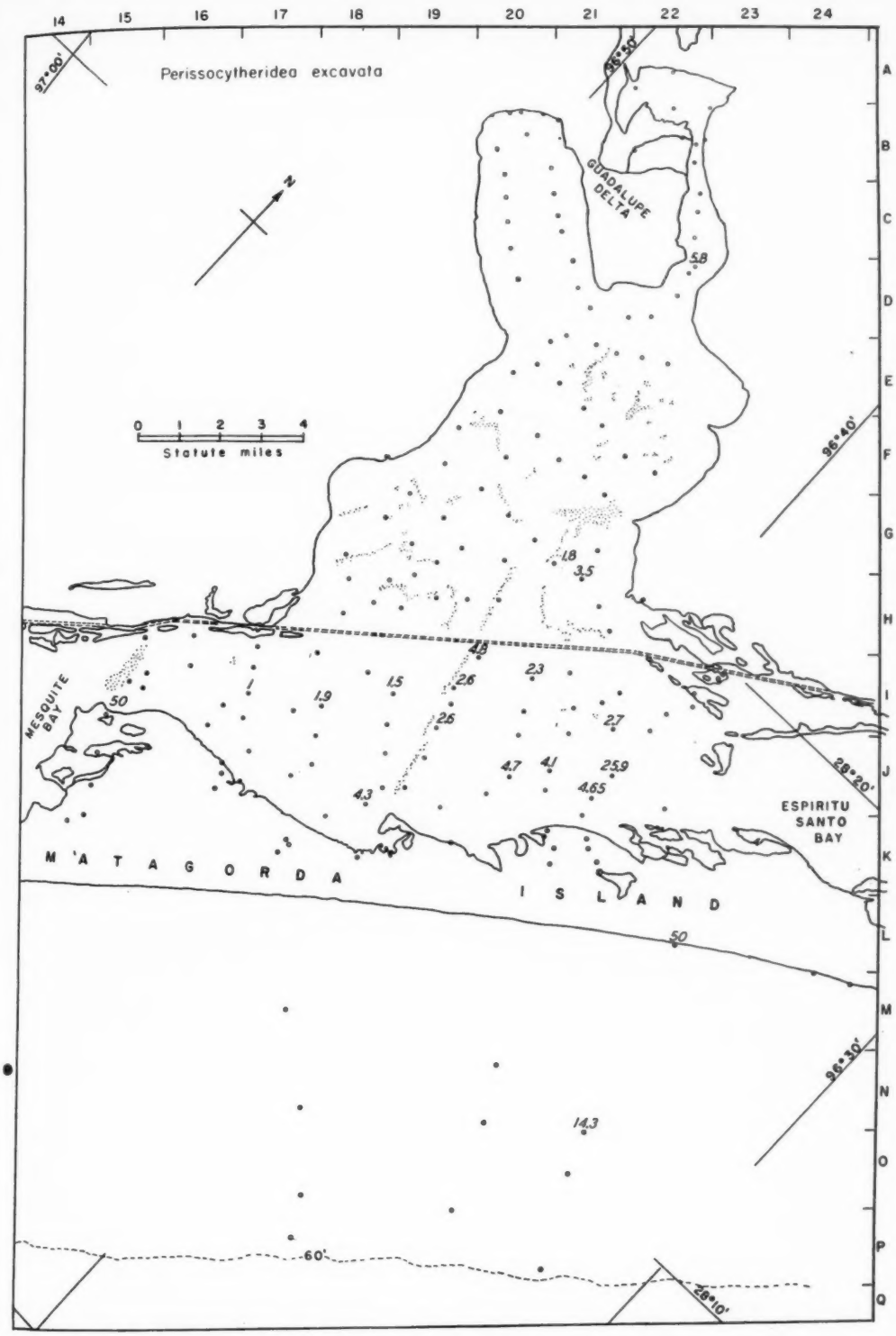

TEXT-FIG. 23—Distribution of *Paradoxostoma atrum* Müller and *Paradoxostoma ensiforme* Brady in per cent of total ostracode population. Stippled areas represent oyster shell reefs.



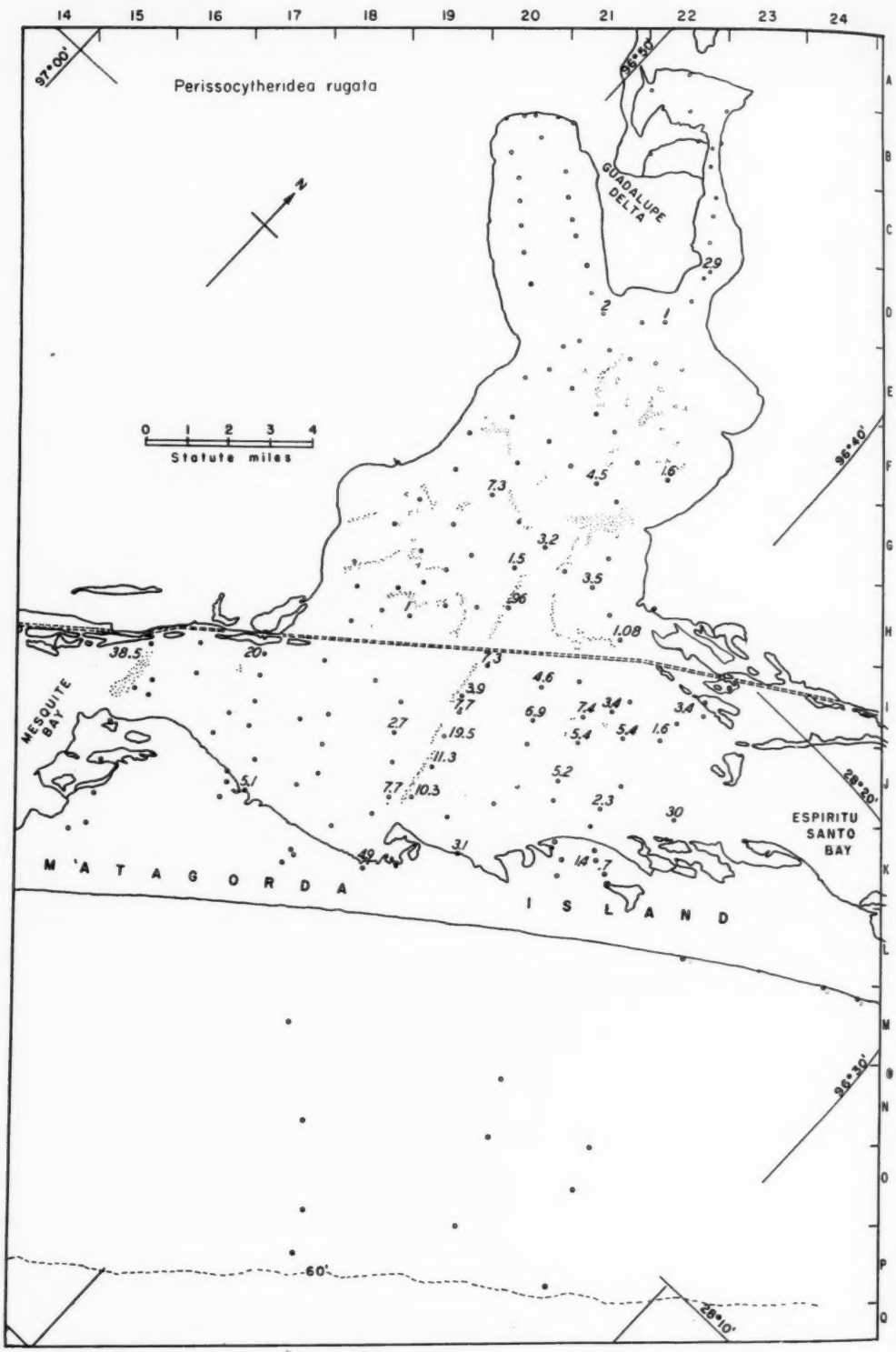

TEXT-FIG. 24—Distribution of *Perissocytheridea bicelliforma* Swain, n. sp. in per cent of total ostracode population. Stippled area represent oyster shell reefs.


Perissocytheridea brachyforma
97°00'
96°50'
96°40'
28°20'
28°10'
GUADALUPE DELTA
MESQUITE BAY
ESPIRITU SANTO BAY
M A T A G O R D A I S L A N D
0 1 2 3 4
Statute miles
N
14 15 16 17 18 19 20 21 22 23 24
A B C D E F G H I J K L M N O P Q

TEXT-FIG. 25—Distribution of *Perissocytheridea brachyforma* Swain, n. sp., in per cent of total ostracode population. Stippled areas represent oyster shell reefs.




TEXT-FIG. *26*—Distribution of *Perissocytheridea brachyforma excavata* Swain, n. subsp., in per cent of total ostracode population. Stippled areas represent oyster shell reefs.




TEXT-FIG. 27—Distribution of *Perissocytheridea rugata* Swain, n. sp., in per cent of total ostracode population. Stippled areas represent oyster shell reefs.

rich in *Cyprideis* and *Candona*. The list of restricted prodelta species is as follows:

*Potamocypris smaragdina* Vavra
*Physocypria pustulosa* (Sharpe)
*Candona lactea* Brady
*Candona obtusa* Brady
*Candona caudata* Kaufmann
*Candona marchica* Müller
*Darwinula stevensoni* (Brady and Robertson)

*Ostracode biofacies of open Gulf.*—In the present collections there are relatively few ostracode specimens from along the Gulf beach of Matagorda Island, in marked contrast to the abundant Foraminifera, particularly *Elphidium discoidale, E. gunteri* and *Quinqueloculina seminula* in the beach sediments. A small ostracode fauna is found in the nearshore open Gulf above 10 fathoms depth, representing species of *Hemicytheridеis?, Cythere?, Puriana* and *Neomonoceratina*. Data on the ostracode populations farther offshore are lacking.

*Relationships of ostracode biofacies to foraminiferal biofacies.* In their study of the Foraminifera from the Rockport area, Parker, Phleger and Pierson (1953, pp. 15–17) recognized the following biofacies:

1. Open Gulf facies, extending seaward from the barrier island beach and characterized by species of *Bigenerina, Bolivina, Buliminella, Cibicidina, Elphidium, Epistonella, Gaudryina, Guttulina, Nonionella, Nouria, Proteonina, Quinqueloculina, Reusella, "Rotalia," Textularia, Triloculina* and *Virgulina*.
   a. Beach subfacies, mainly an open Gulf assemblage but with high frequency of species of *Elphidium* and *Quinqueloculina*.
2. Bay facies, characteristic of San Antonio, Espiritu Santo, Mesquite, Aransas and Capano bays, species of *Ammobaculites, Elphidium* and *Palmerinella*.
   a. Upper San Antonio Bay subfacies, defined on the absence in the upper bay of principally open Gulf species which are widespread in the lower bay.
3. Marsh facies, found in marshes on the bay side of Matagorda Island and at Grassy Point on Guadalupe River delta; species of *Ammoastuta, Arenoparella, Discorbinopsis, Miliammina* and *Trochammina* are restricted to this facies.
4. River facies, evidently not well defined by the Foraminifera because the species of *Lagunulina, Leptodermella, Proteonina* and *Urnulina* found in Guadalupe River are also distributed in the bay.

The river facies of Foraminifera differs from the corresponding river and prodelta facies of the Ostracoda in (1) the fundamental fresh-water nature of most of the ostracodes (2) the greater relative abundance of the ostracodes as compared to the foraminifers in this facies.

The bay facies of both ostracodes and foraminifers is similar in that there is a typical bay population which has become diluted by invaders from the open Gulf. Such dilution by the foraminifers, however, has been much greater than by the Gulf ostracodes because relatively few of the latter species occur importantly in the bay. *Actinocythereis* aff. *A. exanthemata* and *Paracytherella multicarinata* which probably are most typical of the nearshore Gulf occur rarely in the bay and there are a few similar examples among species of *Cytherideis*.

There is a definite lower bay, probably hypersaline, ostracode assemblage that evidently does not have a counterpart in the Foraminifera. Both groups are represented by a nearshore bay and marsh facies or subfacies.

In the open Gulf where the Foraminifera relatively far outnumber the Ostracoda, the former are probably more amenable to biofacies subdivision than the latter. Along the Gulf beaches, ostracodes are not very abundant and have little facies significance, whereas the foraminifers show a useful beach assemblage.

*Relationship of ostracode biofacies to macrofauna facies.* The macroorganisms of San Antonio Bay have been studied by Puffer and others and several facies have been recognized (Puffer, unpublished A.P.I. progress report; Puffer and Emerson, 1953): (1) A lower bay facies consisting of a mixture of offshore and low salinity species of mollusks, species of *Chione, Busycon, Tellidora, Tellina, Sinum, Mellita* and *Trachycardium* were found; (2) *Crassostrea virginica* "reef" complex in irregular patches or ridges in the bay, including species of *Martesia, Brachidontes, Crepidula, Anachis, Mitrella, Odostomia, Seila, Margelia* and *Ischnochiton;* (3) an inter-reef facies of the middle bay, with species of *Chione, Ensis, Tagebus, Nuculana* and *Anadara;* (4) an upper bay facies characterized by abundant specimens of *Rangia, Littoridina* and *Macoma*.

The principal difference between the

macroorganism biofacies and the ostracode biofacies is the extensive development of the oyster "reef" communities which seem to have little or no effect on the ostracode distribution, and the marginal subfacies of ostracodes for which there apparently is no counterpart among the macroorganisms.

The organic debris produced by the macroorganisms undoubtedly is a food-source for some of the ostracodes, either directly or secondarily. It is not known whether specimen-frequency in the ostracodes is directly related to that in the macroorganisms. Scattered data suggest that the ostracodes are not particularly abundant around the oyster banks.

*Living ostracodes from Guadalupe River and San Antonio Bay.* Samples were obtained by Paul L. Engel in March, 1953, from 31 stations in Guadalupe River and San Antonio Bay to determine the ostracode species that were living there in the spring. The locations of the stations at which ostracodes were collected are given in Text-figure 28. The specimens were stained with Rose Bengal solution and those which took the stain were assumed to contain cytoplasm and therefore to have been living when collected. A few specimens which did not take the stain, but which appear to be mature (not molted shells) and which bore appendages also were considered to be living. The distribution of these species is given below. The numbers in parentheses refer to the number of stations in each area that yielded the species.

*Area A.* Slightly above and slightly below mouth of Guadalupe River, 10 stations.

*Candona lactea* Baird (9)
*Limnocythere sanctipatricii* Brady and Robertson (8)
*Candona obtusa* Bronstein (7)
*Candona marchica* Müller (3)
*Cyprinotus* sp. (1)
*Potamocypris* sp. (1)
*Physocypria* cf. *P. pustulosa* (Sharpe) (3)
*Darwinula aurea* (Brady and Robertson) (2)
*Cyprideis littoralis* Brady (9)
*Haplocytheridea?* sp. (2)
*Paracytheridea troglodyta*, n. sp. (4)
*Perissocytheridea brachyforma*, n. sp. (1)
*Cytherura* sp. (1)
*Campylocythere concinnoida*, n. sp. (1)
*Cythermorpha curta* Edwards (1)
*Leptocythere paracastanea*, n. sp. (?)

*Area B.* Near the southern edge of Guadalupe River delta, and adjacent part of upper San Antonio Bay, 7 stations.

*Candona lactea* Baird (1)
*Cyprinotus* sp. (2)
*Astenocypris?* sp. (3)
*Cyprideis littoralis* Brady (2)
*Haplocytheridea* sp. (?)
*Perissocytheridea brachyforma*, n. sp. (2)
*Cytherura johnsoni* Mincher (1)
*Campylocythere concinnoidea*, n. sp. (2)
*Cytheromorpha curta* Edwards (1)
*Leptocythere paracastanea*, n. sp. (5)
*Paradoxostoma? atrum* Müller (7)

*Area C.* In middle and near east shore of middle part of San Antonio Bay.

*Cyprideis littoralis* Brady (2)
*Haplocytheridea* sp. (1)
*Paracytheridea troglodyta*, n. sp. (3)
*?Perissocytheridea brachyforma*, n. sp. (1)
*Cytherura* cf. *C. johnsoni* Mincher (1)
*Cytherura elongata* Edwards (1)
*Leptocythere paracastanea*, n. sp. (2)
*?Loxoconcha* cf. *L. matagordensis*, n. sp. (1)
*Paradoxostoma atrum* Müller

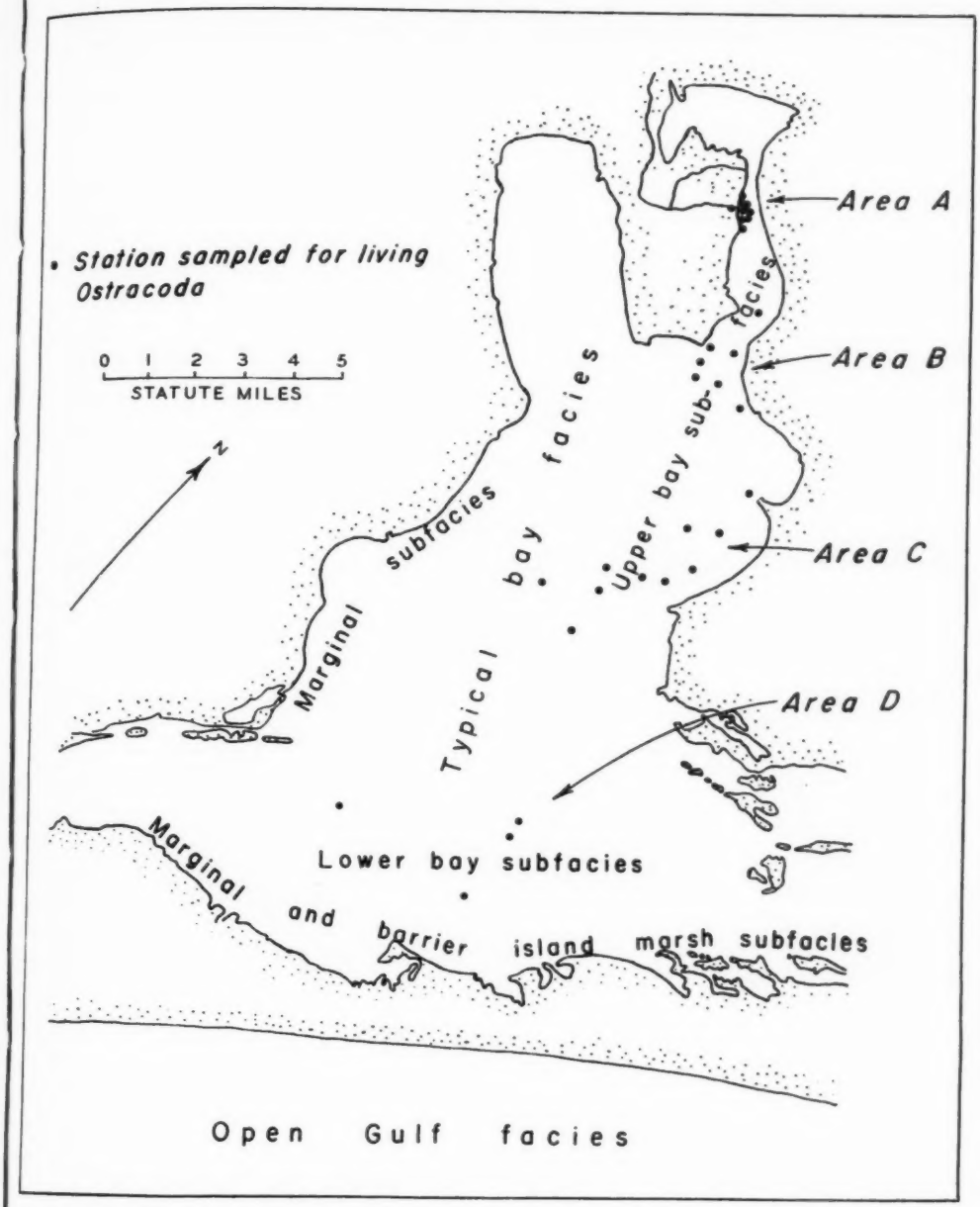
*Area D.* Lower part of San Antonio Bay, 4 stations.

*Cyprideis littoralis* Brady (2)
*Haplocytheridea* sp. (1)
*?Cytherura forulata* Edwards (1)
*Cytheromorpha curta* Edwards (1)
*Leptocythere paracastanea*, n. sp. (1)

The bottom materials coarser than 250 mesh (.061 mm.) in Area A (Text-fig. 28) consist at most stations of plant fragments. This area contained the most abundant living individuals and species in March, 1953.

In Area B the +250 mesh fraction is mainly fecal pellets and variable amounts of quartz. In Area C the coarser fractions of the samples are variable, consisting mainly of quartz grains, fecal pellets and plant fragments in variable amounts. A station of an oyster reef lacked fecal pellets. Area D has mainly quartz grains in the coarser fraction. The numbers of living individuals and species generally decrease away from the river. The quantity of organic detritus also decreases in that direction, in agreement with the data on total N and C (Table 1.)

Species of *Perissocytheridea* and *Cytherura* which dominate the total dead assemblage of ostracodes in this bay are conspicuous by their scarcity among the living specimens. Early spring is evidently the off-




TEXT-FIG. *28*—Sketch map of San Antonio Bay and vicinity showing locations of stations sampled for living ostracodes in March 1953.

season for those species, probably owing partly but not entirely to the lower chlorinity of the bay at this season. *Paradoxostoma*, common in the dead shell assemblage, is abundant among the ostracodes living near the delta in March.

Some rather questionable determinations of species living in San Antonio Bay in July

and August, 1951, were made on the basis of specimens in the washed samples that still retained appendages and knots of viscera within the valves. Three of the species identified as living in July and August, 1951, were not found living in March, 1953. They are *Cytherura costata* Müller, *Microcythere johnsoni* Mincher, and *Paradoxostoma ensiforme* Müller.

### COMPARATIVE ABUNDANCE OF OSTRACODES IN SAN ANTONIO BAY AND OPEN GULF

The distribution of populations of Ostracoda in the sand-sized fraction of the surface samples of San Antonio Bay is shown in Text-figure 29. The grain sizes are mostly coarser than .075 mm. The weight of ostracodes in each sample is an estimation based on a comparison of the number of specimens to a scale which is in turn based on a value of 0.5 mg. per 25 specimens. Six groups of 100 average specimens averaged 2 mg. each. The data have been contoured by using a geometric isopleth interval.

The ostracodes form only up to about 2.5 per cent of the sand-sized fraction, with a rare exception at station 88 in Hines Bay. There is a generally higher concentration of ostracodes down the middle of the bay, near the mouth of Guadalupe River and in Mission Lake north of Guadalupe delta than elsewhere. The higher concentrations occur slightly west of the middle of the bay, apparently because of the high frequency there of *Perissocytheridea*, the genus most abundantly represented by individuals in this bay.

The per cent of ostracodes by weight of the sand-sized fraction of 11 samples from the open Gulf, at depths of less than 10 fathoms, ranges from less than 0.01 to approximately 0.08 per cent, with the average falling around 0.02 per cent. By contrast, the majority of the San Antonio Bay samples had ostracodes exceeding 0.1 per cent of the sand-sized fraction. The bay samples thus contain more than five times as many ostracodes as do equal volumes of the sand fraction of the nearshore open Gulf samples along this part of the coast.

The dominance of the bay fauna in species as well as individuals over the populations of the nearby Gulf is evidently a function of the greater amount of available nutrients in the bay waters. The variation of the ostracode populations within the bay has no very adequate explanation at present. The whole problem is believed to hinge upon the food supply of the ostracodes and this has not been sufficiently investigated.

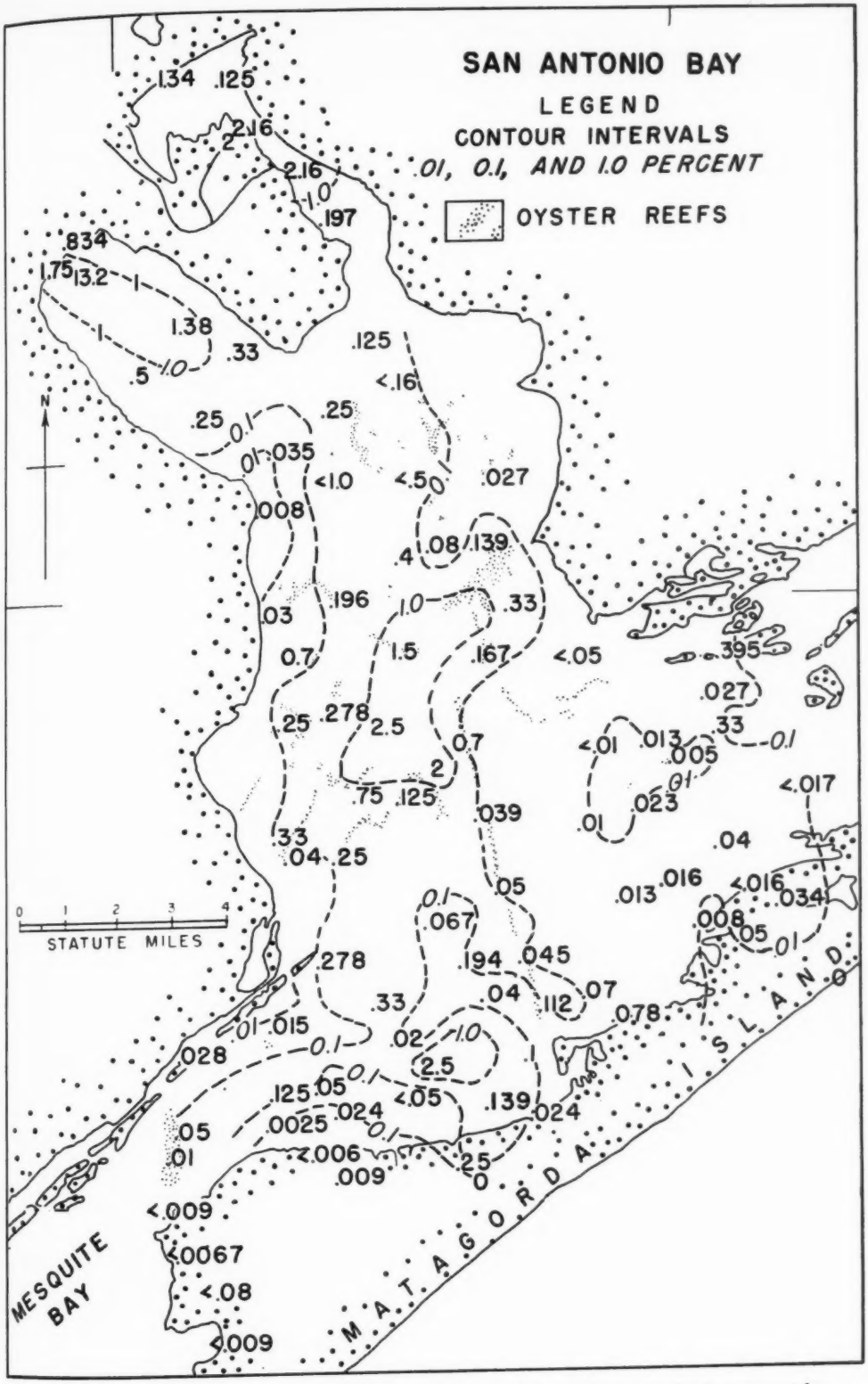
### FREQUENCY VARIATIONS OF TWO POLYSPECIFIC OSTRACODE GENERA IN SAN ANTONIO BAY

The percentage distribution of *Perissocytheridea* and *Cytherura* with respect to total ostracode population at 95 stations has been plotted and contoured in Text-figures 30 and 31. Each station lies one to two miles from its nearest neighbor. The percentages vary so greatly from one station to the next that in order to avoid placing undue emphasis on any one station, a geometric isopleth interval has been used.

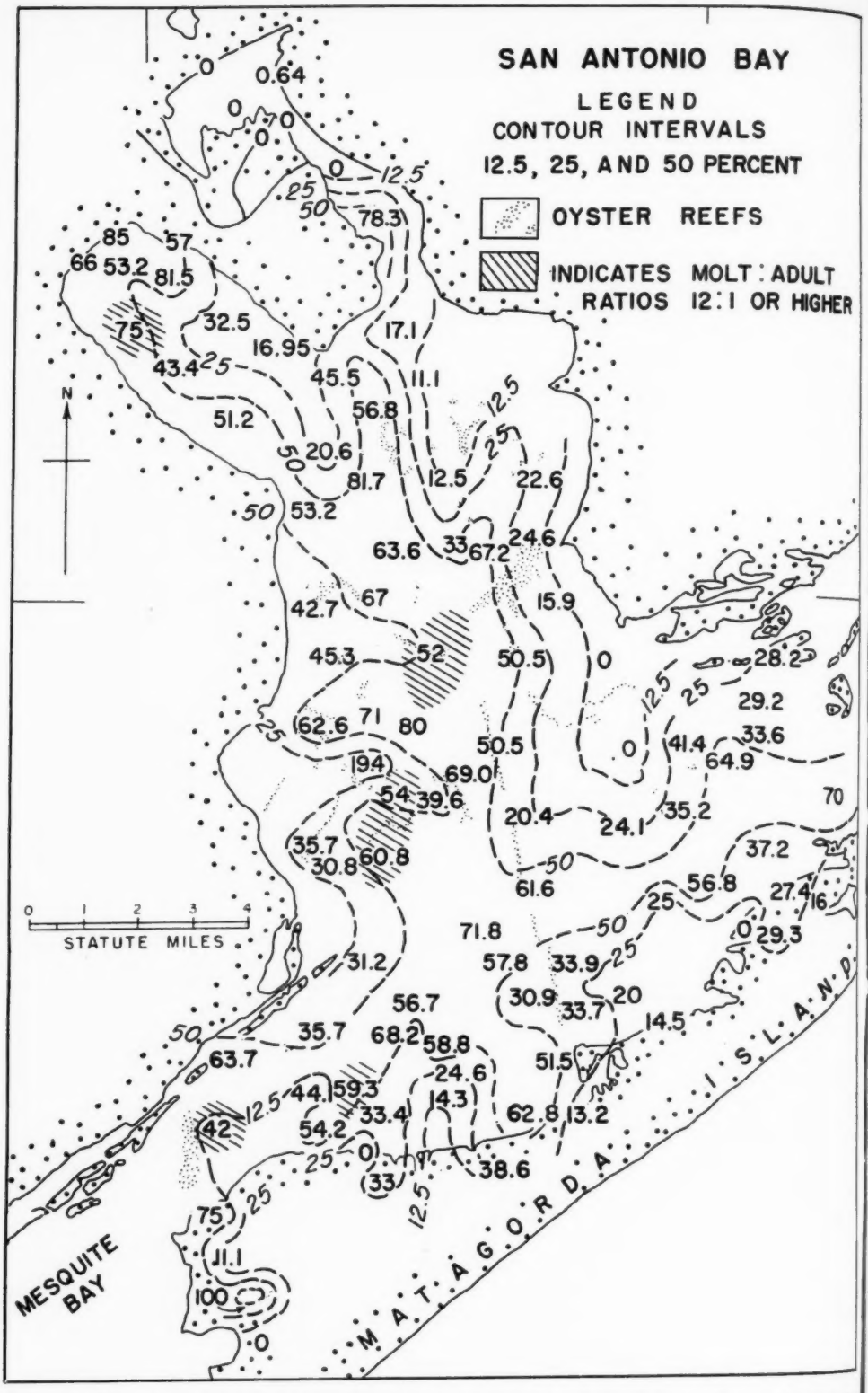
These two genera are the most abundantly represented by species and individuals among the San Antonio Bay ostracodes. *Perissocytheridea* and particularly *P. brachyforma*, n. sp., is most abundant in southwestern Hines Bay and in the middle of the estuarine as well as the lagoonal parts of San Antonio Bay. Its greatest frequency is slightly west of the middle of San Antonio Bay probably because of the effects of the river water along the eastern side of the bay. *Cytherura*, especially *C. johnsoni* Mincher, is very sparse to absent in the middle of the estuary as well as around most of Guadalupe Delta, and is much more abundant along the margins of the lower part of the estuary. *Cytherura* thus has a more or less complementary relationship in frequency to *Perissocytheridea* in the estuarine part of the bay. The increase of *Cytherura* along the eastern margin of the bay when the fresh river waters are most likely to be concentrated suggests that this genus favors more hyposaline waters than *Perissocytheridea*. Sufficient chlorinity data are not now available to prove or disprove this possibility.

### FOOD SUPPLIES

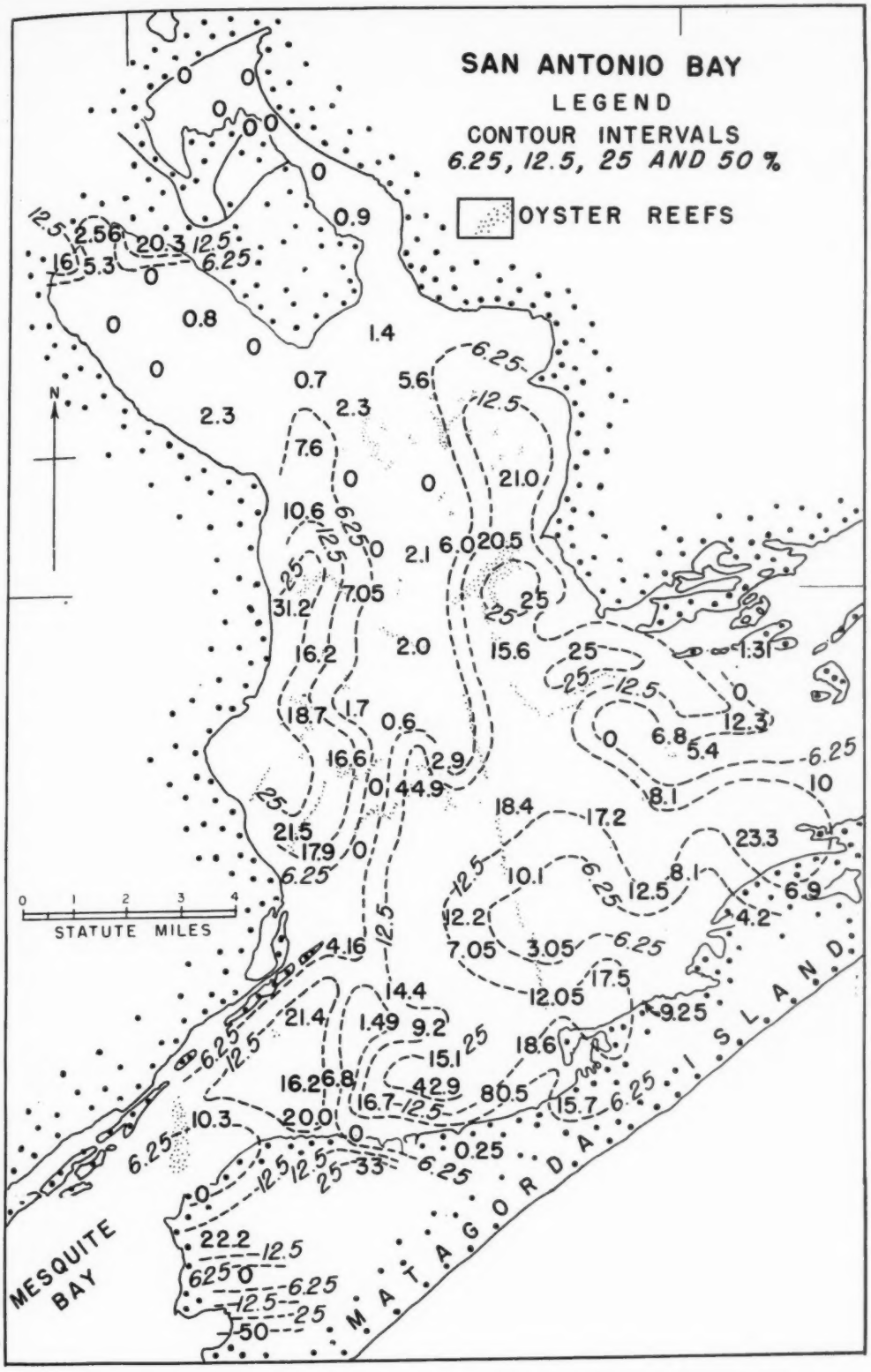
Ostracoda are known to feed on bacteria, diatoms, various algae, protozoans, and the detritus of larger plants and animals (Hoff, 1942). Kesling (1951) found that cultures of *Cypridopsis vidua* died when fed only cooked or raw meat, although Wolge-




TEXT-FIG. 29—Distributions of populations of Ostracoda in surface samples in per cent by weight of sand-sized fraction at each station. Stippled areas represent oyster shell reefs.




TEXT-FIG. *30*—Distribution of *Perissocytheridea* in per cent of total population of Ostracoda. Stippled areas represent oyster shell reefs. Diagonally-lined areas represent molt to adult ratios of 12:1 or higher, possibly indicating the more favorable growth centers.




TEXT-FIG. *31*—Distribution of *Cytherura* in per cent of total ostracode population. Stippled areas represent oyster shell reefs.

muth reported success with this diet in aquarium cultures of fresh-water ostracodes.

Specific data as to the food of the ostracodes in the Rockport area are lacking. W. T. Rothwell (personal communication) found abundant ostracodes in *Zostera* (eel grass) fields in California bays, having normal or high salinity, but no such fields occur in San Antonio Bay, according to R. H. Parker of the Scripps field party. Turtle grass (*Thallassia*) is present in northern Copano and in lower Aransas Bays, close to shore, areas in which ostracodes are not abundant.

Some information concerning food supplies of fresh-water and marine ostracodes in other localities is presented below with the view that the data may be in part applicable to the Rockport area.

*Ostracode food supplies in a temperate lake.*—A brief study of the ostracodes in Coon Lake, Anoka County, Minnesota, was made in May, 1953, by R. E. Grant, N. Thein and E. R. Schmitz under the writer's direction. This is a typical eutrophic lake in an iceblock depression on the Anoka sand plain (Mankato substage of Wisconsin drift). The lake bottom consists of sand and gyttja (highly organic silt and sand with much fecal matter) in various proportions. The lake exceeds 30 feet in depth and in summer develops temperature stratification with the thermocline at 12–15 feet. The pH of the water at the time of sampling varied from 5 in the greater depths to 6.5 near shore, but these low values were due to the winter oxygen depletion from which the lake had not yet recovered. The normal summer pH would be slightly alkaline. The lake is surrounded by a deciduous forest, and there are several areas of pond weed and *Typha* (cattail) development in the shallow parts of the lake.

Nine species of ostracodes were obtained from 18 localities ranging from 1 foot to 27 feet in depth. Because of the earliness of the season for this latitude, small total populations were obtained. Two-thirds of the specimens were obtained from depths of 5 feet or less. About four-fifths (80 out of 107) of the shallow water specimens were living when collected, whereas only one-sixth (10 out of 60) of the deep water specimens were living. Species of *Candona*, *Cypridopsis*, *Cyclocypris*, *Heterocypris*, *Paracandona*, and *Cypria* are represented in the fauna. *Paracandona* was restricted to the shallow water. *Cypria* cf. *C. lacustris* was twice as abundant in the deep water as in the shallow. The other species were more abundant in the shallow waters. *Candona* is represented by four species, the others by only one.

The highest ostracode populations occur in the pondweed at the southern edge of the lake where the bottom is sandy. The prevailing winds are from the southwest, and the finer debris is swept away from this part of the lake bottom into deeper water toward the north. The living ostracodes were found in the pondweed rather than on the bottom, and presumably were feeding directly on the pondweed itself. The food source for the *Cypria* in the deeper hypolimnetic parts of the lake appeared to be the fresher organic debris that had been swept from the shoaler areas. Some debris from the preceding season was perhaps also being utilized. No appreciable plankton crop had formed by that date. At the north end of the lake, the bottom materials are principally gyttja, consisting of plankton and pondweed drifted there by the wind. This type of sediment, although rich in nutritive content, is evidently not favored by ostracodes. The ostracodes found in the pondweed in the southern part of the lake had well-calcified shells; the *Cypria* in the deeper water were poorly calcified. Whether the degree of calcification is seasoned or is strictly controlled by the environment is not known.

In summary, the ostracodes of Coon Lake in May 1953 mostly showed a preference for a shallow water, somewhat turbulent, pondweed environment, rather than an organic-rich gyttja bottom and apparently fed mainly from the pondweed stalks. *Cypria* was less selective than the other ostracodes but seemed even to prefer deeper water where the food source was to be found in the gyttja.

The low salinity fluvial and prodelta ostracodes of San Antonio Bay probably found their principal food supply in the algal material which is plentifully represented by fibrous debris in the washed samples.

*Ostracode food supplies near La Jolla and*

*San Diego, California.*—In January, 1952, the writer was able to collect from the beach zones near the Scripps Institution of Oceanography, La Jolla, and on the tidal flat in Mission Bay, San Diego, California.

The localities at La Jolla were all along the exposed coast where surf action is moderate to heavy. The following zones were sampled: (1) Green algae on cliff above high spray zone, wet by seep: no ostracodes; (2) High spray zone with *Littorina:* no ostracodes; (3) Lower mussel (*Mytilus*)-coralline algae zone: "*Cythere,*" *Hemicythere, Xestoleberis;* ostracodes were clinging to coralline algae and feeding from parts not coated with lime; (4) brown algae zone: a myodocopid ostracode and "*Cythere,*" clinging to plants and feeding from them; (5) upper part of eel-grass zone with brown ribbon kelp: *Cythere,* feeding on plants; (6) lower eel-grass zone, submerged at low tide: "*Cythere,*" "*Cythereis,*" *Xestoleberis,* feeding on eel-grass. Zone 2 is wet by spray at high tide; zones 3 and 4 are exposed at low tide; zones 5 and 6 are mostly submerged at low tide.

A striking feature was the complete absence of empty ostracode shells in these samples; the surf apparently removes the individuals no longer able to maintain their holds on the plants.

Two samples were collected at low tide in Mission Bay: (1) highly organic ooze just below low tide level, very similar in texture to the gyttja of eutrophic lakes, swarming with copepods, nematodes, etc.: rare *Bythocypris?,* apparently an unfavorable environment for ostracodes; (2) a small intertidal pool with green algae: *Xestoleberis, Loxoconcha,* probably utilizing algae as main food source. The Mission Bay ostracodes had poorly calcified shells.

In general the ostracodes from these two environments in southern California are plant feeders and seem to favor the moderately turbulent environment which keeps the bottom swept free of thick accumulations of organic debris.

## FOSSIL REPRESENTATIVES OF THE OSTRACODE FAUNA

A very significant resemblance exists between the San Antonio Bay ostracode fauna and that described by Mincher (1941) from the middle Miocene Pascagoula clay of west-central Mississippi. The Pascagoula is believed to represent a brackish-water facies of the Choctawhatchee formation of the eastern Gulf region, on the basis of the ostracodes and the clam *Rangia johnsoni* Dall. All of the ostracode genera of the Pascagoula are represented in San Antonio Bay, namely *Cyprideis* ("*Anomocytheridea*"), *Cytherura, Cytheromorpha, Perissocytheridea* and *Microcythere. Cytheromorpha pascagoulensis* is probably identical with *Cytheromorpha curta* Edwards of the Duplin marl, upper Miocene of North Carolina, and with the Recent *Cytheromorpha* of the San Antonio Bay collections. *Microcythere johnsoni* of the Pascagoula seems identical with the *Microcythere* of San Antonio Bay and "*Microcythere*" *moresiana* Stephenson of the Pascagoula is similar to *Paradoxostoma atrum* Müller of the present collection.

The Foraminifera *Elphidium gunteri* Cole, *Eponidella cushmani* Stephenson and *Rotalia beccarii* Linné were also found in the Pascagoula and suggest a bay environment.

It is questionable whether faunas such as these should be considered simply as brackish. Low chlorinity periods in the bays are frequently offset by chlorinity values higher than normal sea water, late in the summer and during other intervals of excessive evaporation. In shallow bays, chlorinity-layering of the water probably does prevail or may never exist, except near river mouths where a low chlorinity surface layer may occur (Table 1).

The ostracode species either must adapt themselves to considerable ranges in chlorinity or must restrict their life spans to periods when the chlorinity is suitable for them. Some sort of balance of both factors may prevail for the species most successful in the bays.

Other fossil occurrences of the San Antonio Bay ostracodes are as follows, with the maximum age given in each case:

*Cypridopsis vidua* Müller—Pleistocene
*Cyprideis torosa* Jones—Pleistocene
*Limnocythere sanctipatricii* Brady and Robertson—Pleistocene
*Cyprideis littoralis* Brady—Pleistocene
*Cyprideis locketti* (Stephenson)—Pliocene
*Haplocytheridea bradyi* Stephenson—Pliocene
*Darwinula aurera* (Brady and Robertson)—Pliocene

*Haplocytheridea bassleri* Stephenson—Miocene
*Paracytheridea nodosa* (Ulrich and Bassler)—Miocene
*Hemicythere conradi* Howe and McGuirt—Miocene
*Cytheromorpha curta* Edwards—Miocene
*Cytherura forulata* Edwards—Miocene
*Cytherura elongata* Edwards—Miocene
*Cytherura johnsoni* Mincher—Miocene
*Microcythere johnsoni* Mincher—Miocene

## SUMMARY

The Ostracoda from the surface centimeter of sediment at 172 stations in San Antonio Bay and scattered stations on Matagorda Island and in the open Gulf of Mexico above 10 fathoms depth represent both low salinity and marine types, and in addition, a few indicate brackish-water.

San Antonio Bay is an estuary 14 miles long separated from the open Gulf by a mature barrier beach, Matagorda Island. Guadalupe River has built a delta 3 miles long at the head of the bay. The bay averages about 4 feet deep and the water temperatures range between 13° and 31° (+5 to 10°); tidal effects are small. The waters are mostly slightly alkaline except near the river mouth and the redox potential in the surface sediment is mildly oxidizing. Two principal water masses occur in the bay: the river water moves down the middle of the bay and is deflected southwest in the lower bay by the second water mass of Gulf origin which enters lower San Antonio Bay from the northeast.

Three ostracode biofacies have been recognized in the area: (1) river and prodelta facies, (2) bay facies with midbay, marginal and lower bay subfacies, (3) open Gulf facies. The ostracode biofacies are characterized by restricted lateral distribution of genera, species, and subspecies; some species, of course, occur throughout the area but their frequencies are low in environments not favorable to them.

The Foraminifera, as studied by Parker, Phleger and Pierson, show well developed biofacies here, and in general these have the same distribution as the ostracodes. The ostracode fluvial and prodelta facies is better developed than the corresponding foraminiferal facies, and in the open Gulf and along the outer beach of Matagorda Island the foraminiferal facies are better developed than those of the ostracodes.

Samples for living ostracodes obtained in March, 1953, showed the living forms to decrease in number away from the river mouth, but this decrease was mostly in the low salinity species which were most abundantly represented by living individuals at that time of year. Living specimens of *Perissocytheridea* and *Cytherura*, the genera most abundant in terms of individuals in the bay, were scarce in March, 1953. Also, living forms of these genera were apparently scarce in July and August, 1951, a time for which few data are available.

The ostracode populations of San Antonio Bay are about five times larger than in the nearby open Gulf. Locally in a small "lake" north of Guadalupe Delta ostracode coquinas of "freshwater" species and the brackish-water *Cyprideis* occur.

The two most abundant genera in San Antonio Bay, *Perissocytheridea* and *Cytherura*, are each represented by several species. When the population of each genus is plotted as per cent of the total ostracode population, it is found that the distribution of each genus roughly complements that of the other in the main bay. This cannot be due to overcrowding unless each has a very restricted environment. *Cytherura* tends to predominate marginally where the bottom is cleaner sand. It may be inferred, though not proved, that *Cytherura* lives principally attached to benthic vegetation and feeds from it; whereas *Perissocytheridea* prefers to burrow and feed in the more highly organic muds of the middle part of the bay. The locomotory appendages of *Perissocytheridea* (Text-fig. 39, 5a, b) are stouter and better suited to burrowing than are those of *Cytherura* (Text-fig. 39, 1a–c).

The food supplies of the San Antonio Bay ostracodes have not been studied specifically. Some comparative data from other areas are presented. In the fluvial and prodelta area chlorophytic (green) and myxophytic (blue-green) algae may have been the most important source of food.

One-third of the ostracode species of San Antonio Bay are represented by fossils ranging as far back as middle Miocene. Some of the shells may be reworked specimens brought in by the river or washed in from the Live Oak barrier-beach facies of the Pleistocene Beaumont clay which adjoins the lower part of San Antonio Bay.

### OSTRACODE CLASSIFICATION USED IN THIS PAPER

In some other recent papers dealing with Mesozoic and Cenozoic ostracodes, the writer has avoided use of subfamilies of the Cypridae and Cytheridae, because of the many uncertainties in the existing subfamily structure (Swain, 1948, 1949, 1952; Swain and Peterson, 1951, 1953). However, it now seems desirable to make use of subfamily categories in describing the San Antonio Bay ostracodes, because it seems very likely that ecological significance may attach to those generic groups.

The following classification of generic and higher categories is used:

Order OSTRACODA Latreille, 1802 (Class, Pokorny, 1953)
- Suborder PODOCOPA Sars, 1866 (Order Podocopida Pokorny, 1953)
  - Family CYPRIDIDAE Baird, 1846
    - Subfamily CYPRIDINAE Kaufmann, 1900
      - Genus ASTENOCYPRIS Müller, 1912
      - Genus CYPRINOTUS Brady, 1885
    - Subfamily CYPRIDOPSINAE Kaufmann, 1900
      - Genus POTAMOCYPRIS Brady, 1870
      - Genus CYPRIDOPSIS Brady, 1867
    - Subfamily CANDONINAE Kaufmann, 1900
      - Genus CANDONA Baird, 1845
    - Subfamily CYCLOCYPRIDINAE Kaufmann, 1900
      - Genus PHYSOCYPRIA Vavra, 1877
  - Family DARWINULIDAE Brady and Norman, 1889
    - Genus DARWINULA Brady and Robertson, 1885
  - Family BAIRDIIDAE Sars, 1887
    - Genus BYTHOCYPRIS Brady, 1880
  - Family CYTHERIDAE Baird, 1850
    - Subfamily LIMNOCYTHERINAE Sars, 1925
      - Genus LIMNOCYTHERE Brady, 1867
    - Subfamily CYTHERIDEINAE Sars, 1925
      - Genus CYPRIDEIS Jones, 1856
      - Genus HAPLOCYTHERIDEA Stephenson, 1936
      - Genus PERISSOCYTHERIDEA Stephenson, 1938
      - Genus PARACYTHERIDEA Müller, 1894
    - Subfamily CYTHERURINAE Müller, 1894
      - Genus CYTHERURA Sars, 1866
    - Subfamily LOXOCONCHINAE Sars, 1926
      - Genus LOXOCONCHA Sars, 1866
      - Genus CYTHEROMORPHA Hirschmann, 1909
      - Genus LEPTOCYTHERE Sars, 1925
    - Subfamily XESTOLEBERINAE Sars, 1928
      - Genus HEMICYTHERIDEIS Ruggieri, 1952
    - Subfamily PARADOXOSTOMINAE Müller, 1894
      - Genus PARADOXOSTOMA Fischer, 1855
  - Family TRACHYLEBERIDAE Sylvester-Bradley, 1948
    - Subfamily TRACHYLEBERINAE Sylvester-Bradley, 1948
      - Genus ACTINOCYTHEREIS Puri, 1953
      - Genus PURIANA Coryell, 1953
    - Subfamily HEMICYTHERINAE Puri, 1953
      - Genus HEMICYTHERE Sars, 1925
    - Cytheridae of uncertain subfamily relationships
      - ?Genus CYTHERE Müller, 1785
      - Genus PARACYTHERETTA Triebel, 1941
      - Genus ACUTICYTHEREIS Edwards, 1944
      - Genus MONOCERATINA Roth, 1928
      - Genus MICROCYTHERE Müller 1894
      - Genus NEOMONOCERATINA Kingma, 1948

The subfamilies of the Cytheridae are in uncertain status, and the present grouping of genera is probably subject to many corrections. Although there is no present agreement among workers in this field as to the shell characters most useful in recognition of subfamilies, it appears that the general shape, major configuration of the surface (other than spines, nodes, pits, etc.), together with the hinge structure are most important.

The subfamily Cytherinae if defined to include only those genera with hinge structures like *Cythere* Müller, i.e., a taxodont type of hinge, would therefore exclude genera with terminal high rounded teeth and deep sockets. Such genera would include the heavy-shelled forms *Cytheretta*, *Paracytheretta*, *Buntonia*, *Basslerites*, etc., as well as light shelled *Campylocythere*, etc. Whether existing subfamilies as Hemicytherinae and Limnocytherinae could properly receive these genera is not certain. It seems improbable that the family Trachyleberidae and subfamily Trachyleberinae, as now formed, would be a satisfactory place for the problematical genera, and much additional taxonomic study is needed.

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U. S. National Museum, Division of Marine Invertebrates.

## SYSTEMATIC DESCRIPTIONS

### Family CYPRIDIDAE Baird, 1846

Shell variable in size, shape, and surface ornamentation; calcareous or corneous; midventral margin curved inward; hinge formed of a bar and groove, or rabbet-groove; muscle scar a median group of spots, typically not radially or linearly arranged, with additional, more anteroventral spots in most genera; inner lamellae present; line of concrescence and inner margin not coinciding. Marine and fresh-water; Ordovician to Recent; worldwide distribution.

### Subfamily CYPRIDINAE Kaufmann, 1900

Shell of variable shape and size, up to several millimeters in length; probably a polyphyletic, unnatural association of genera; shell typically subovoid to subtriangular with greatest height typically median to anteromedian, posterior end more pointed than anterior; surface typically with tiny pits, pustules or reticulations; left valve typically the larger; hinge surface typically curved, rarely long and straight, consisting of a groove in larger valve for reception of simple edge of smaller valve; muscle scar typically a rather compact median to anteromedian group of four or five spots together with one or two additional more anteroventral spots. Marine and fresh-water; Paleozoic?, Mesozoic to Recent; worldwide distribution.

### Genus ASTENOCYPRIS Müller, 1912

*Leptocypris* SARS, 1903, Archiv. Math. Naturv., Christiana, v. 25, No. 8, p. 28. (not *Leptocypris* Boulenger, 1900)

Elongate, highest medially, much compressed; dorsum moderately arched; ventrum sinuous; posterior margin truncated; surface longitudinally striated; inner lamellae very narrow. Type species: *Leptocypris papyracea* Sars, 1903.

#### ASTENOCYPRIS? sp.
Plate 59, figure 7

Shell elongate-subelliptical; highest about two-fifths from anterior end; dorsal margin gently convex; ventral margin nearly straight to slightly sinuous. Terminal margins rounded, the anterior the broader; the posterior extended below. Valves nearly equal in size, the left slightly larger. Convexity moderate, greatest medially. Surface of shell bears tiny longitudinal striations.

Hinge line marked by simple overlap of right valve by left. Inner lamellae narrow and poorly calcified, broadest anteriorly; vestibule present. Radial canals fairly numerous, single, short. Muscle scar not clearly seen, but it seems to consist of an anteromedian group of four spots arranged somewhat obliquely toward anteroventral area.

Length of figured left valve 0.77 mm., height 0.31 mm., convexity 0.11 mm.

*Remarks.*—The shape, inner shell structures, and tiny surface striations all suggest a relationship of this rare form to *Astenocypris*. *Ilyodromus* Sars is a similar genus but has a straighter hinge line, more distinct cardinal angles, and broader inner lamellae. The present species seems close to *Astenocypris papyracea* (Sars), a Recent East Asian species but the data for comparison are not at present complete.

*Occurrence.*—The figured left valve is from San Antonio Bay, No. 114A.

### Genus CYPRINOTUS Brady, 1885

Subtriangular, valves compressed; dorsum strongly convex, subangulate medially; ventrum slightly concave; posterior margin angulate below midheight, truncate above and below; free margins of right valve finely spinose; terminal margins of left valve with hyaline border; left valve overlaps right terminally; right valve may extend beyond left dorsally. Surface smooth. Inner lamellae rather narrow, broadest anteriorly. Type species, *C. cingalensis* Brady, 1886.

#### CYPRINOTUS SALINUS (Brady)
Plate 59, figures 6a,b

*Cypris strigata* BRADY, 1862, Intell. Observer, vol. 1, p. 452, fig. 6 [not O. F. Müller, 1785].

*Cypris salina* (BRADY), BRADY, 1868, Trans. Linn. Soc., London, vol. 26, p. 368, pl. 28, figs. 8–13; SARS, 1891, Forh. Selsk. Christian, no. 1, p. 56; G. W. MÜLLER, 1900, Zoologica, vol. 30, p. 76, pl. 16, figs. 1, 2, 10, 12; 1912, Das Tierreich, pt. 31, p. 165; BRONSTEIN, 1947, Fauna U. S. S. R., vol. 2, no. 1, p. 136, fig. 62.

*Cypris prasina* BRADY and NORMAN, 1889, Trans. Roy. Dublin Soc., ser. 2, vol. 4, p. 78; BRADY and NORMAN, ibid., vol. 5, p. 56.

*?Eucypris palermitana* DADAY, 1900, Ostr. Hungar., p. 58.

Shell elongate in side view, highest medially; dorsal margin moderately convex, weakly angulated medially; ventral margin slightly convex in right valve; terminal margins broadly and nearly uniformly rounded. Anteroventral margin of right valve finely tuberculated. Left valve larger than right, extending beyond the other except posterodorsally. Valves moderately convex, greatest convexity at a position slightly behind middle, shell generally more tumid posteriorly than anteriorly.

Surface of shell bears tiny shallow pits of irregular size and distribution, some connecting, others widely spaced. Hinge of left valve consists of a groove for reception of edge of right; it can be considered to consist of two parts; anterior portion lies mostly anterad of position of greatest height, is broad, open anteriorly and is strongly overhung by outer margin of valve; posterior portion very narrow and occupies valve edge in plane of commissure. Muscle scar is a slightly anteromedian group of six spots. Inner lamellae narrow, but of greatest width anteriorly; inner margin and line of concrescence separated. Radial canals numerous, closely spaced. Hinge of right valve anteriorly consists of the simple extended valve edge that fits beneath corresponding overhanging edge of left; posteriorly, hinge edge of right valve curves downward so that when received into hinge groove of opposite valve, it is slightly recessed.

Length of a complete specimen, possibly an immature molt (Pl. 59, fig. 6a) 1.16 mm., height 0.70 mm., convexity 0.56 mm.

*Remarks.*—The shape and anteroventral tuberculations of the right valve margin provide a comparison of these specimens with *C. salinus*, an European brackish-water ostracode.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 64A; rare off Guadalupe Delta, Matagorda Island marshes, and on island in southeast San Antonio Bay.

### Subfamily CYPRIDOPSINAE Kaufmann, 1900

Shell small to medium-sized (generally less than 1 mm.), uniform to subtriangular; dorsum moderately to strongly arched; ventrum typically concave; ends rounded, extended below midheight; valves more or less unequal; surface smooth, densely pitted, pustulose or spinose; inner lamellae typically very narrow. Fresh and brackish? water; Permian?, Tertiary to Recent; worldwide distribution.

### Genus POTAMOCYPRIS Brady, 1870

*Candonella* CLAUS, 1891, part, Arbeit aus dem Zool., Inst. Wien., v. 10, pt. 2, pp. 147–216; cf. MÜLLER, 1912, Das Tierreich.

Elongate-reniform, compressed, highest medially; dorsum moderately arched; ventrum concave; terminal margins extended below, posterior slightly narrower; right valve strongly overlaps left dorsally and ventrally; surface densely pitted; inner lamellae moderately broad at both ends. Type species, *Bairdia fulva* Brady, 1868. Tertiary to Recent.

### POTAMOCYPRIS SMARAGDINA (Vavra) Plate 60, figures 4a–c

*Cypridopsis smaragdina* VAVRA, 1891, Arch. naturw. Landesf. Böhmen, vol. 8, no. 3, pp. 80–81, fig. 26. SHARPE, 1897, Bull. Ill. Lab. Nat. Hist., vol. 4, pp. 470–471, pl. 48, figs. 11, 12.

*Potamocypris smaragdina* (Vavra), DADAY, 1900, Ostr. Hung. SHARPE, 1903, Proc. U. S. Nat. Mus., vol. 26, p. 992, pl. 65, fig. 5–7; 1918, in Ward and Whipple, Freshwater biology, p. 808, figs. 1254 a-c. HOFF, 1942, Ill. Biol. Mon., vol. 14, no. 1, 2, p. 154, pl. 8, figs. 118–124. FURTOS, 1933, Ohio Biol. Surv., vol. 5, pp. 435–436, pl. 6, figs. 10–14; DOBBIN, 1941, Univ. Wash. Publ. Biol., vol. 4, pp. 231–232, pl. 2, figs. 1–6.

Shell sublanceolate to elongate-subreniform in side view; highest about three-fifths from anterior end; dorsal margin strongly convex, with the steeper slope anterior; ventral margin gently concave; anterior margin broadly rounded and extended below; posterior margin narrowly rounded and bluntly acuminate, strongly extended below. Left valve larger than right, overlapping and extending beyond right along free margins; along dorsum right extends slightly beyond left. Convexity median to slightly anteromedian. Valve surfaces essentially smooth except for numerous tiny pores representing the normal canals; long bristles protrude from pores resulting in a very hairy aspect of the shell; hairs are all backswept toward

posterior. Anteroventral portion of left valve bears a narrow submarginal flange; a similar very short subtriangular flange occurs posteroventrally.

Hingement consisting of a slight groove in the dorsal face of right valve for reception of simple edge of left. Calcified inner lamellae lacking, but there are chitinous inner lamellae in terminal and ventroterminal portions. Adductor muscle scar located at middle or slightly posterior to middle of valve; it consists of a group of six spots. Radial canals numerous and closely spaced terminally.

Length of a figured shell (Pl. 60, fig. 4a) 0.55 mm., height 0.29 mm., convexity 0.22 mm.

*Remarks.*—The general shape, internal features and abundant bristles on the surface of this species distinguish it from the other ostracodes of San Antonio Bay. *P. smaragdina* is an ubiquitous fresh-water ostracode in North America and Europe. The present specimens seem to comply with features prescribed for the species by Hoff (1942, p. 155).

*Occurrence.*—San Antonio Bay, No. 136A. Restricted to upper part of San Antonio Bay off Guadalupe River Delta except for one rare occurrence in the middle bay. Previously reported to occur commonly in permanent lakes and streams in North America and Europe.

### Genus CYPRIDOPSIS Brady, 1867

*Candonella* CLAUS, 1891 (part) Arbeit aus dem Zool., Inst. Wien, vol. 10, pt. 2, pp. 147–216; cf. MÜLLER, 1912, Das Tierreich.
*Proteocypris* BRADY, 1906?, Trans. Nat. Hist. Soc. Northumb,. vol. 1, pp. 330–336, pls. 9, 10.
*Pionocypris* BRADY and NORMAN, 1896, Trans. Roy. Dublin Soc., vol. 5, pp. 621–746.

Reniform, subtriangular, not elongated, moderately to strongly convex, with greatest convexity postmedian; dorsum strongly arched, angulated medially, truncated on either side of position of greatest height; venter concave; anterior margin the narrower; left valve slightly the larger; surface pitted, pustulose, spinose. In part parthenogenetical. Type species, *Cypris vidua* Müller, 1776. Fresh- and brackish-waters; Permian?, Recent; world wide distribution.

### CYPRIDOPSIS VIDUA (Müller)
Plate 60, figures 6a–c

*Cypris vidua* O. F. MÜLLER, 1876, Zool. Danicae Prodromus, Havniae, p. 199.
*Cypridopsis vidua* BRADY, 1868, Intell. Observer, vol. 12, p. 117.
*Pionocypris vidua* BRADY and NORMAN, 1896, Trans. Roy. Dubl. Soc., vol. 5, p. 726. (A more nearly complete synonomy is given by Kesling, 1951.)

Shell elongate-subreniform in lateral view; greatest height approximately at midlength but may vary from slightly in front to slightly behind that position; dorsal margin strongly convex, obtusely angulate at position of greatest shell height; ventral margin nearly straight; anterior broadly rounded, slightly extended below; posterior margin more narrowly rounded, extended below. Left valve larger than right, overlapping and extending slightly beyond the other along dorsal, anterior and ventral margins; posteriorly overlap is inconspicuous. Valves strongly inflated, with greatest convexity approximately median. Entire surface of shell ornamented by small pits in the positions of the normal canals, with interspaces approximately equal to diameter of pits. Long bristles protrude from normal canals and densely clothe surface of shell in well preserved specimens.

Hinge of left valve consists of a long, very narrow, faintly crenulate groove, occupying straight dorsal edge posterior to position of greatest height; a dorsally adjacent, broad, accommodation groove; an anterior elongate fairly wide socket-like depression that marks the antero-mid-dorsal end of the selvage groove; posteriorly there seems to be little or no corresponding widening of the selvage groove. Hinge surface of right valve not clearly seen. Muscle scar consists of a slightly anteromedian group of about six longitudinally elongate spots and two, separate, more anteroventral spots.

Length of a left valve (Pl. 60, fig. 6a) 0.68 mm., height 0.41 mm., convexity 0.25 mm. Length of a complete shell (Pl. 60, fig. 6b) 0.63 mm., height 0.41, convexity 0.44 mm.

*Remarks.* This form is difficult to place in a described species, but it seems close to *C. vidua* in general outline and strong convexity of the valves. The narrowness of the

posterior margin and the variable position of the greatest height are somewhat atypical.

*Occurrence.* Figured specimens, San Antonio Bay, No. 136A. The species was found only in the Guadalupe River distributaries and in the small bay north of the delta. It evidently cannot withstand more than a trace of salinity, but can tolerate rather low pH (Hoff, 1942). The species is one of the commonest fresh-water ostracodes in North America and Europe and has also been recorded in the tropics.

### Subfamily CANDONINAE Kaufmann, 1900

Shell medium to large in size, more or less elongate, subreniform, compressed to moderately convex; typically higher behind middle of shell; dorsum arched; venter more or less concave; anterior margin typically more narrowly rounded than posterior; valves equal or unequal; surface smooth or pitted; inner lamellae typically broad. Fresh- and brackish-water; Jurassic to Recent; worldwide distribution.

### Genus CANDONA Baird, 1845

*Eucandona* DADAY, 1900, Ostracoda Hungariae, Budapest, p. 242.
*Typhlocypris* VEDJOVSKY, 1882, Tierische Organismen in den Brunnengewassern von Prag, Prag, p. 64.

Elongate medium-sized, subreniform, moderately convex, highest posterior to middle; dorsum strongly arched; venter concave; anterior margin generally the narrower; left valve slightly larger than right; right may overlap along venter; surface smooth or finely punctate; shell substance cloudy white in Recent forms; inner lamellae broadest anteriorly; radial canals few, simple, widely spaced. Males slightly larger than females, but nearly of same proportions. Type species, *Cypris candida* O. F. Müller, 1776. Fresh- and brackish-water. Permian?, Triassic to Recent, worldwide distribution.

### CANDONA OBTUSA Bronstein

Plate 59, figures 1a, b; Text-figures 38, 2a,b

*Candona obtusa* BRONSTEIN, 1947, Fauna of U.S.S.R., vol. 2, no. 1, Freshwater Ostracoda, p. 252, fig. 157.

Shell elongate-subreniform in side view; dorsal margin moderately convex with steep, truncated posterodorsal slope and gentler anterodorsal slope; greatest height slightly posterior to midlength; ventral margin slightly concave medially; anterior margin narrowly rounded; most extended ventral to midheight; posterior margin broader, distinctly truncated. Left valve slightly larger than right. Shell cloudy, translucent; surface smooth. Greatest convexity slightly postmedian.

Hinge of right valve consists of the simple smooth edge which fits into a narrow, weak groove in left valve. Inner lamellae moderately broad along entire free margins; inner margins characterized by a slightly elevated lip or rim, especially at anterior end; surface of lamella slopes very steeply along venter, so that vestibule is narrower there than terminally. Muscle scar typical of other species of *Candona*. Pore canals not clearly seen.

Antennules consist of five podomeres which are all subequal in length, but are progressively narrower distally; first and fourth podomeres with a single seta each; second and third with two setae, the dorsal ones being four to five times length of podomere; ultimate podomere with four long setae. Furcal ramus slightly curved, convex dorsally, with dorsal seta about twice as long as width of furca and located one-third from its distal end; furcal claws slightly convex ventrally, in length less than half that of furca, and each bearing three or four denticles.

Length of a figured right valve (Pl. 59, fig. 1b) 0.87 mm., height 0.51 mm., convexity 0.26 mm.

*Remarks.*—This species is more unequal-ended than *C. lactea* Baird, but not so unequal-ended nor so concave ventrally as *C. marchica* Hartwig, with which it is here associated. *C. caudata* Kaufmann is much more pointed posteriorly. The species under consideration is very close to *C. candida* (O. F. Müller) in general shape, but the shell of the latter as figured by Sars (1928, pl. 32) is much higher posteriorly. Bronstein (1947, p. 321) considered the posterodorsal concavity of the margin to be characteristic of *C. obtusa* and the present specimens are close to if not identical with that species.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 136A. Fairly

abundant in Guadalupe River and in upper bay near mouth of delta; less common to rare in upper third of bay; absent except at one station in lower bay. The species was originally described from the U.S.S.R.

### CANDONA LACTEA Baird

Plate 59, figures 2a–c; Text-figure 38, 1

*Candona lactea* BAIRD, 1850, Proc. Zool. Soc. London, p. 255, pl. 18, figs. 25–27. BRADY, 1868, Mon. Rec. Brit. Ostracoda, p. 382, pl. 24, figs. 55–58. BRADY, CROSSKEY and ROBERTSON, 1874, Post-Tert. Entomostraca, p. 134, pl. 1, figs. 14–16. BRADY and NORMAN, 1889, Trans. Roy. Dublin Soc., vol. 4, p. 100.

*Candona detecta* BRADY (var.), 1868, op. cit. p. 384, pl. 24, figs. 35–38; pl. 37, fig. 2. BRADY, CROSSKEY and ROBERTSON, 1874, op. cit., pl. 1, figs. 7–9.

Shell subelliptical in side view; dorsal margin gently convex; ventral margin slightly concave medially; terminal margins broadly and equally rounded. Left valve much larger than right, overlapping and extending beyond edge of right around entire margin. Shell substance fairly clear, not cloudy as in typical *Candona;* surface smooth and shiny, except for scattered pits, where normal canals emerge. Valves moderately convex; greatest convexity median.

Hinge simple; edge of right valve fits into a weak groove in edge of left. Inner lamellae narrow, sloping steeply along venter; vestibule narrow; marginal zone of moderate width, traversed by radial canals that are fairly numerous (about 15) anteriorly, but are few and widely spaced ventrally and posteriorly. Muscle scar typical for *Candona.*

Furcal ramus slightly curved, convex dorsally, with length of dorsal seta about equal to width of ramus; distal claws strongly bent, the dorsal one more so, both are concave dorsally and weakly denticulate.

Length of figured complete specimen (Pl. 59, fig. 2a) 0.59 mm., height 0.32 mm., convexity 0.31 mm.

*Remarks.*—The subelliptical shape and narrow inner lamellae, with well developed radial canals distinguish this species from other representatives of *Candona* in the Rockport area.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 136A. The species is common in the upper part, and is rare in the middle part of the bay. This species is widespread in Europe and North America.

### CANDONA CAUDATA Kaufmann

Plate 59, figure 5

*Candona caudata* KAUFMANN, 1900, Rev. Suisse Zool., vol. 8, pp. 365–68, pl. 24, figs. 16–20, pl. 26, figs. 17–23. SARS, 1928, Crustacea of Norway, pp. 76–77, pl. 35. KLIE, 1938, Die Tierwelt Deutschlands, vol. 34, p. 68, figs. 223–225. VAVRA, 1909, Die Süsswasserfauna Deutsch., vol. 11, p. 96, figs. 391–392. ALM, 1915, Zool. Bidrag, Uppsala, vol. 4, p. 190, fig. 67.

*Candona elongata* MÜLLER, 1912 (not Herrick, 1879), Das Tierreich, p. 140. (Hoff, 1942).

*Candona acuminata* BRADY and NORMAN, 1889, Trans. Roy. Soc. Dublin, vol. 4, p. 104, pl. 10, figs. 4–6. (Bronstein, 1947).

Valves elongate-sublanceolate, highest slightly posterior to midlength; dorsal margin moderately convex; ventral margin conspicuously sinuous, concave slightly anterad of midlength; anterior margin rounded, extended below; posterior margin bluntly acuminate, strongly extended below; the ventral margin in left valve notched immediately anterad of posteroventral marginal bend. Complete shell not seen; left valve has free edge with selvage border apparently for reception of smaller right valve. Convexity moderate; most convex medially. Shell cloudy white, surface smooth.

Hingement not clearly seen, apparently with simple overlap of left over right valve. Inner lamellae of moderate width, broadest anteriorly; line of concrescence and inner margin widely separated, except midventrally. Radial canals very numerous and closely spaced along entire free margin, but are very short because of narrow marginal zone. Muscle scar typical of genus, consisting of a compact slightly anteromedian group of 5 spots and two additional widely separated more anteroventral spots.

Length of figured left valve 1.25 mm., height 0.57 mm., convexity 0.24 mm.

*Remarks.*—The elongate shell, and particularly the caudate posterior end, distinguish this species from other *Candona* in the Rockport area.

*Occurrence.*—The figured specimen is from San Antonio Bay, No. 92A. Rare in upper

part of bay. Elsewhere, the species is common in Europe and North America.

### CANDONA MARCHICA Hartwig

Plate 59, figures 3a, b; Text-figure 38, 3a–d

*Candona marchica* HARTWIG, 1899, Sitzungsber. Ges. naturf. Freunde Berlin, p. 183. KAUFMANN, 1900, Rev. Suisse Zool. p. 389, pl. 27, figs. 1–3; pl. 28, figs. 1–5; pl. 31, fig. 19. VAVRA, 1909, Die Süsswass. Deutschl., vol. 11, p. 91, figs. 364, 365. ALM, 1915, Zool. Bidrag, Uppsala, vol. 4, p. 131, fig. 75. SARS, 1928, Crustacea of Norway, p. 80, pl. 38, fig. 1.

*Candona rostrata* MÜLLER (part), 1900, Deutschl. Süsswasser-Ostracoden. Zoologica, vol. 30, p. 5, figs. 2–3, 7–14. Var. *terminalis* DADAY, 1900, Ostracoda Hungariae. Budapest, p. 244. (Bronstein, 1947).

Shell reniform in side view; highest about one-third from posterior end; dorsal margin moderately convex, slightly straightened medially, subtruncate fore and aft of this position; ventral margin strongly concave anteromedially; anterior margin rounded, extended strongly below midheight; posterior margin much more broadly rounded, slightly extended below. Left valve larger than right, overlapping and extending rather strongly beyond right anteriorly, midventrally and along dorsal slopes. Convexity moderate, valves most convex posterior to middle. Valve substance cloudy white and light tan, surface smooth.

Hinge consists of a distinct but narrow groove in dorsal edge of left valve into which fits edge of right; knife-edged flanges lie at ends of hinge groove in left valve and strongly overlap on right valve. Inner lamellae broad anteriorly, narrower elsewhere; vestibule widest anteriorly, almost nonexistent midventrally where line of concrescence and inner margin coincide, and narrow posteriorly. Marginal zone correspondingly narrow anteriorly and broader posteriorly and ventrally. Radial canals very numerous (over 60) anteriorly, less numerous ventrally and posteriorly; line of concrescence scalloped terminally. Normal canals few and widely spaced. Muscle scar typical for genus.

Antennules with six podomeres that have the ranges in size and shape illustrated (Text-fig. 38, 3d); only first podomere has a ventral short seta; second, third and fifth podomeres have single long dorsal setae, the fourth with two setae; ultimate podomere with two very long dorsal and three short stout terminal setae. Antennae with four terminal setae, all of subequal length and slightly longer than ultimate podomere. Furca sinuate, with a short dorsal seta about one-fourth from distal end of furca, and a small ventral seta at distal end; claws strongly curved, concave dorsally; in length about half that of furcal ramus, nondenticulate. Ejaculatory tube of male has seven rings of spikes as is typical of genus, each wreath relatively long, with short intervening necks, although this condition would vary with degree of contraction of tube; peripheral zone with a finely and delicately fibrous radiating structure.

Length of a figured specimen (Pl. 59, fig. 3a) 1.05 mm., height 0.64 mm., convexity 0.50 mm.

*Remarks.*—The blunt kidney-shaped outline with strongly concave ventrum distinguish this species from the other San Antonio Bay candonids. It is much less common than either *C. obtusa* or *C. lactea*.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 90A. Rare to frequent in upper part of bay near Guadalupe Delta.

### Subfamily CYCLOCYPRIDINAE Kaufmann, 1900

Shell small, less than 1 mm. long, subovate to subtriangular, highest medially; dorsum strongly convex; ventrer nearly straight; ends rounded; anterior generally the narrower; greatest length below midheight; valves compressed to strongly convex; greatest in posterior half; valves subequal to strongly unequal; surface smooth, pitted, reticulated or lined; inner lamellae narrow. Fresh and brackish water. Quaternary; worldwide distribution.

### Genus PHYSOCYPRIA Vavra, 1898

Subovate to subtriangular, moderately convex; highest postmedially; dorsum strongly arched to umbonate; venter slightly convex; anterior margin the narrower; valves strongly unequal, either left or right may be the larger, overlapping

strongly dorsally and ventrally; free margins of left or right valve serrate or spinose. Type species, *P. bullata* Vavra, 1898. Recent worldwide distribution.

PHYSOCYPRIA PUSTULOSA (Sharpe)
Plate 60, figures 5a,b

*Cypria pustulosa* SHARPE, 1897, Bull. Ill. Lab. Nat. Hist. vol. 4, pp. 461–62. KOFOID, C. A., 1908, ibid., vol. 8, p. 258.
*Cypria (Physocypria) pustulosa* SHARPE, 1918, The Ostracoda, in Ward and Whipple, Fresh water biology, p. 821, figs. 1287 a-e.
*Physocypria pustulosa* (Sharpe), MÜLLER, 1912, Das Tierreich, p. 134. FURTOS, 1933, Ohio Biol. Survey, vol. 5, p. 470, pl. 16, figs. 10–11. HOFF, 1942, Ill. Biol. Mon., vol. 19, p. 121, pl. 7, fig. 98.
*Physocypria globula* FURTOS, 1933, Ohio Biol. Survey, vol. 5, pp. 468–69, pl. 16, figs. 1–9 (Hoff, 1942, p. 121).

Shell ovate in side view; highest medially, dorsal margin moderately convex; ventral margin slightly convex; terminal margins broadly and uniformly rounded. Left valve slightly larger than right, overlapping along free margins. Valves moderately convex, with greatest convexity posterior to middle. Surface of shell smooth and shiny.

Hinge consists of a narrow, shallow groove in slightly overhanging dorsal face of left valve for reception of edge of right; a rabbet-groove borders ridge dorsally in right valve. Muscle scar a medially placed compact group consisting of four large spots. Inner lamellae narrow, attaining greatest width anteriorly; inner lamellae and line of concrescence slightly separated; radial canals numerous anteriorly. Right valve bears a prominent selvage ridge along free margins and outer margin is denticulate ventroterminally. Left valve bears a corresponding less distinct selvage groove, but lacks the terminal denticles in the specimens studied.

Length of figured left valve (Pl. 60, fig. 5a) 0.55 mm., height 0.37 mm. Length of a complete shell 0.52 mm., height 0.36 mm., convexity 0.25 mm.

*Remarks.*—Hoff (1942) presents a detailed analysis of *Physocypria pustulosa*. The present species seems to conform in general outline, convexity, and presence of terminal right valve denticles to features described for *P. pustulosa*.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 136A. Rare to frequent in Guadalupe River and in upper part of bay near delta. The species has been recorded rather widely in North America.

Family DARWINULIDAE Brady and Norman, 1889

Shell elongate-ovate; more narrowly rounded and less convex in front than behind; surface typically smooth; right valve larger than left; hinge simple, undifferentiated; muscle scar consists of numerous radially arranged spots. Fresh and brackish waters. Carboniferous? to Recent; worldwide distribution.

Genus DARWINULA Brady and Robertson, 1885

*Polycheles* BRADY and ROBERTSON, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 25 (name preoccupied).
*Darwinella* BRADY and ROBERTSON, 1872, ibid., vol. 9, p. 50 (name preoccupied).

Elongate, oblong or ovate; anterior narrower than posterior; surface smooth; right valve much larger than left; hingement formed by simple right valve overlap; muscle scar consists of about twelve elongate radially arranged spots anterior to middle; calcified inner lamellae nearly lacking. Type species, *Argilloecia? aurea* Brady and Robertson, 1870. Fresh- and brackish-waters. Carboniferous? to Recent; worldwide distribution.

DARWINULA AUREA (Brady and Robertson)
Plate 60, figures 3a–c

*Argilloecia? aurea* BRADY and ROBERTSON, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 16, pl. 8, figs. 4, 5.
*Polycheles stevensoni* BRADY and ROBERTSON, ibid., p. 25, pl. 7, figs. 1–7; pl. 10, figs. 4–14.
*Darwinella stevensoni* (Brady and Robertson) BRADY and ROBERTSON, 1872, Ann. Mag. Nat. Hist., ser. 4, vol. 10, p. 50. BRADY, CROSSKEY and ROBERTSON, 1874, Post Tertiary Entomostraca, Paleontogr. Soc., p. 141, pl. 2, figs. 13–17.
*Darwinula stevensoni* (Brady and Robertson) BRADY and NORMAN, 1889, Trans. Roy. Dublin Soc., ser. 2, vol. 4, pp. 122–123, pl. 10, figs. 7–13; pl. 13, figs. 109; pl. 23, fig. 5. SARS, 1928, Crustacea of Norway, p. 145, pl. 67. HOFF, 1942, Ill. Biol. Mon. p. 157, pl. 9, figs.

125, 126. SWAIN, 1947, Jour. Paleontology, vol. 23, p. 180, pl. 32, figs. 16–17.
*Darwinula improvisa* TURNER, 1895, Second Rept. State Zool. Minn., pp. 336–337, pl. 81, figs. 1–3, 13 (Müller, 1912).
*Darwinula aurea* (Brady and Robertson) Müller, 1912, Das Tierreich, p. 240.

Shell elongate-oval to sublanceolate in side view, highest about one-third from posterior end; dorsal and ventral margins converge toward anterior, that of dorsum slightly convex, venter straight to slightly sinuous; anterior margin more narrowly rounded than posterior, subacuminate, extended below; posterior margin slightly extended above. Right valve a little larger than left overlapping strongly along venter as seen from below, but not extending appreciably beyond the other as viewed from the side. Valves strongly convex, with greatest convexity in posterior third. Surface smooth and polished.

Hinge simple, consisting of a slight groove in edge of left valve for reception of edge of right. Inner lamellae in present specimens occurs only along anterior margin when it is very narrow and scarcely, if at all, calcified; a few tiny radial canals present anteriorly. Muscle scar consists of a compact, subcircular group of nine small spots, situated anterior to midlength.

Length of a figured shell (Pl. 60, fig. 3c) 0.67 mm., height 0.28 mm., convexity 0.29 mm.

*Remarks.*—The present specimens comply in shape, overlap and other shell features with *D. aurea*. Males of the species are almost unknown, and the reproduction is generally parthenogenetical (Hoff, 1942, p. 159).

*Occurrence.*—Figured specimens, San Antonio Bay, No. 92A, 136A. The species is rare to frequent in the upper part of the bay especially near front of Guadalupe Delta; it also is rare at two stations in the middle of the bay. Worldwide in fresh-water environments.

## Family BAIRDIIDAE Sars, 1888

Bairdiinae SARS, 1923, Crustacea of Norway, pts. 3, 4, p. 62 (subfamily of Cypridae).

The characteristics of this family, so far as the shell is concerned have not yet been adequately defined. Bassler and Kellett (1934, p. 39) give the following diagnosis- "minute, mostly reniform or elongate: ovate, corneo-calcareous shells with thin, more or less unequal valves, one overlapping the other ventrally or dorsally, or both." Grekoff (in Piveteau, v. 3, 1953, p. 282) diagnoses the family by the nature of its muscle scar (rosette-formed). As presently constituted the family ranges from Ordovician to Recent, is mostly marine, but has fossil fresh-water representatives in the Mesozoic which have been referred to *Bairdiocypris* Kegel. The latter genus, which was described from the Devonian, has recently been placed in the Healdiidae by Krömmelbein (1952).

### Genus BYTHOCYPRIS Brady, 1880

Shell similar to *Bairdia* McCoy but dorsal margin more evenly convex, lacking the truncated anterodorsal and posterodorsal slopes that generally, although by no means exclusively, characterize *Bairdia*. A careful diagnosis of the genus would be desirable. Cordell (1952) has discussed some of the problems relating to fossil *Bythocypris*. Type species *B. reniformis* Brady 1880 (=*Bairdia bosquetiana* Brady 1866, Brady and Norman, 1889, p. 119) (also see Sylvester-Bradley 1947, p. 194). Typically marine; Ordovician to Recent; worldwide distribution.

### BYTHOCYPRIS? sp.
Plate 59, figure 4

This rare form is characterized by sublanceolate outline; arched dorsum, concave venter, broadly rounded anterior margin, narrowly rounded and ventromedially extended posterior margin and very faintly pitted surface. The hinge is simple and the muscle scar, although not clearly observed, seems to be in a rosette pattern. The inner lamellae are relatively broad.

The relationships of the species are not clear, but the muscle scar and general shape are like *Bythocypris*.

Length of figured specimen 0.31 mm., height 0.16 mm., convexity of valve .075 mm.

*Occurrence.*—Figured specimen, San An-

tonio Bay, No. 68A; not seen elsewhere in San Antonio Bay.

Family CYTHERIDAE Baird, 1850

The following summary of the family is translated from Grekoff (in Piveteau, 1953, p. 282):

This, the largest family of Mesozoic-Recent ostracodes, is divided into numerous subfamilies. The muscle impressions are constant in their assembly and are formed of four impressions ranging along a vertical line preceded by one or two others, or composed of only one impression (presumably referring to late Paleozoic genera, as *Basslerella* Kellett).

The carapaces are of variable form, of generally solid, calcareous constitution, and frequently strongly sculptured. The valves are generally a little unequal in size and are articulated dorsally by a more or less well-developed denticulate hinge.

The genera are distinguished principally by their denticulate hinges; taxodont (Cytherideinae) or heterodont (Cytherinae). Certain similar genera also present constant variations in the configuration of the muscle impressions. Marine and fresh-water. Paleozoic to Recent; worldwide distribution.

Subfamily LIMNOCYTHERINAE Klie, 1938 (LIMNICYTHERINAE Sars, 1925)

Shell thin, often poorly calcified, not strongly sculptured; usually with protuberances or furrows; shape subquadrate, with subparallel dorsum and venter; ends rounded; hingement weak, marginal areas broad. Fresh and brackish waters; Tertiary to Recent; worldwide distribution.

Genus LIMNOCYTHERE Brady, 1868

*Limnicythere* BRADY 1868, Trans. Linn. Soc. London, vol. 26, pp. 353–495.

Shell elongate subquadrate in larger males, sublanceolate in females, ends rounded; shell thin, surface ornamented by pits, low ridges, generally on ventrer, and nodes; hinge weak, consisting of terminal right valve teeth and left valve sockets; marginal area broad, with numerous radial canals. Type species, *Cythere inopinata* Baird, 1843?. Tertiary to Recent; worldwide distribution.

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EXPLANATION OF PLATE 59

FIGS. *1a, b—Candona obtusa* Bronstein. Exterior views of two right valves. *1a* has extraneous surface material. San Antonio Bay, No. 136A, ×33. (p. 607)

*2a–c—Candona lactea* Baird. *2a*, Left side of a complete shell; *2b*, interior of a right valve; *2c*, ventral view of a complete shell. San Antonio Bay, No. 136A, ×33. (p. 608)

*3a, b—Candona marchica* Hartwig. *3a*, right side of a complete shell; *3b*, interior of a left valve. San Antonio Bay, No. 90A, ×33. (p. 609)

*4—Bythocypris?* sp. Interior of an immature right valve, questionably in this genus. San Antonio Bay, No. 68A, ×50. (p. 611)

*5—Candona caudata* Kaufmann. Left valve interior. San Antonio Bay, No. 92A, ×33. (p. 608)

*6a, b—Cyprinotus salinus* Brady. *6a*, Interior of an immature left valve; *6b*, interior of an adult right valve showing tiny spines along ventral and terminal margins. San Antonio Bay, No. 64A, ×33. (p. 604)

*7—Astenocypris* sp. Exterior of a left valve. San Antonio Bay, No. 3A, ×50. (p. 604)

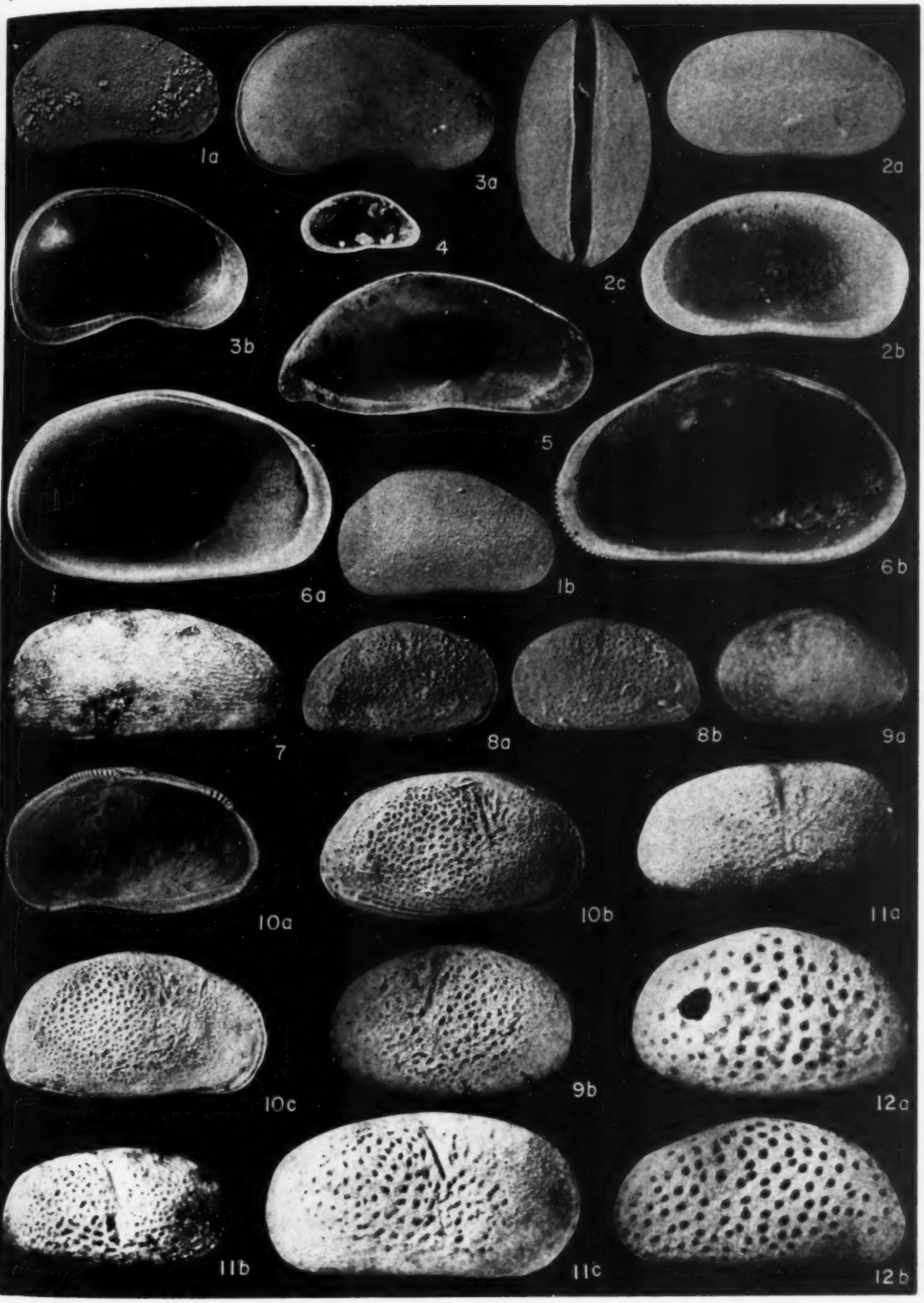
*8a, b—Cyprideis torosa* (Jones). *8a*, Exterior of a right valve; *8b*, exterior of a left valve, both showing low surface nodes. San Antonio Bay, No. 136A, ×33. (p. 616)

*9a, b—Haplocytheridea bassleri* Stephenson. *9a*, Exterior of an immature left valve. San Antonio Bay, No. 45A, ×27. *9b*, Exterior of a female? left valve. San Antonio Bay, No. 35A, ×33. (p. 617)

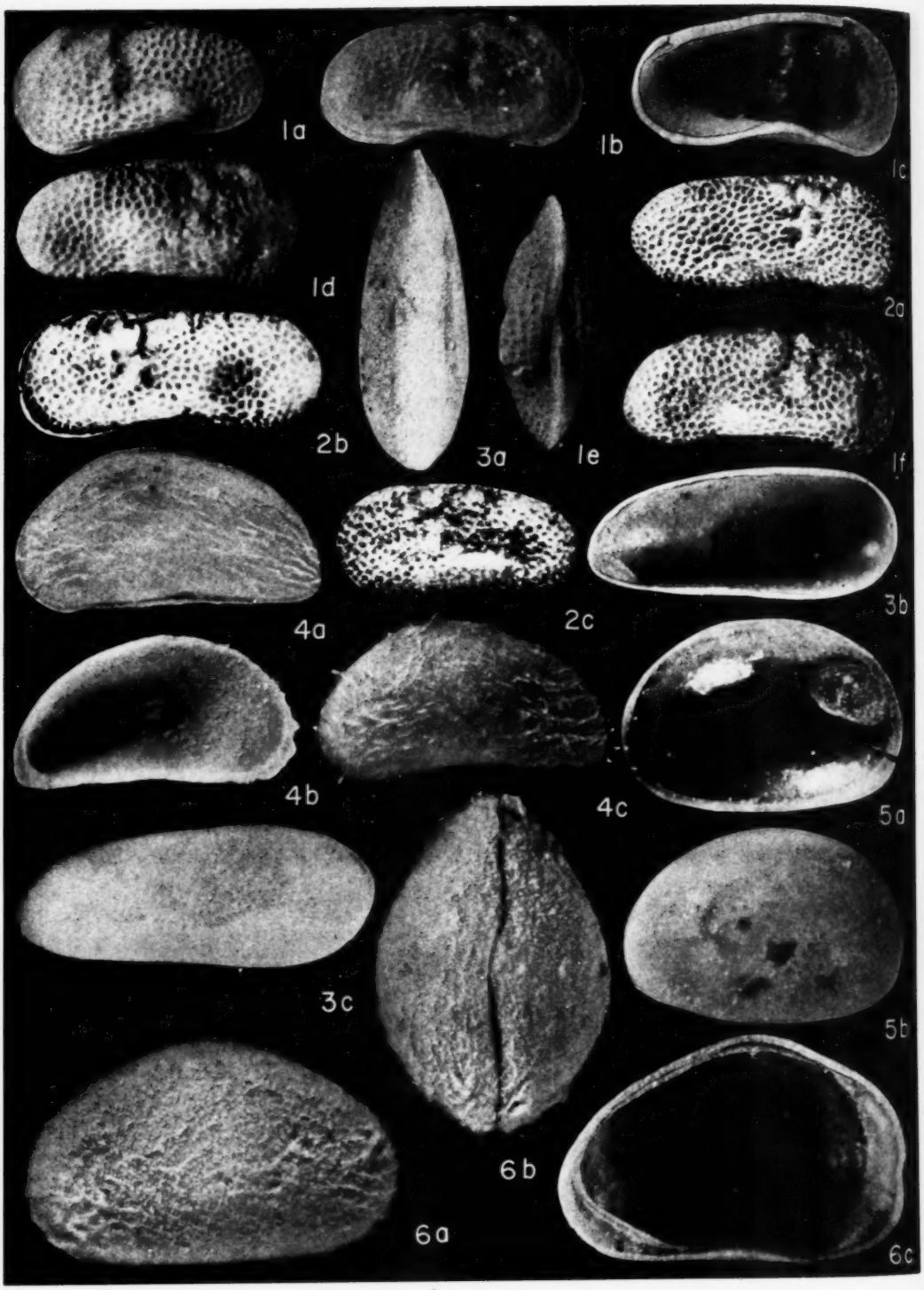
*10a–c—Cyprideis locketti* (Stephenson). *10a*, Interior of a male? right valve; *10b*, right side of a complete female? shell; *10c*, exterior of a male? right valve. San Antonio Bay, No. 136A, ×33. (p. 615)

*11a–c—Cyprideis littoralis* Brady. *11a*, Exterior of an immature right valve having surface only weakly pitted, ×50; *11b*, exterior of an immature right valve, ×33. San Antonio Bay, No. 16A. *11c*, Exterior of a right valve. San Antonio Bay, No. 6A, ×50. (p. 615)

*12a, b—Haplocytheridea bradyi* (Stephenson). *12a*, Exterior of a female? right valve; *12b*, Exterior of a male left valve. San Antonio Bay, No. 35A, ×50. (p. 618)




Swain, Texas Recent ostracodes




Swain, Texas Recent ostracodes

### LIMNOCYTHERE SANCTIPATRICII Brady and Robertson

Plate 60, figures 1a–f, 2a–c; Text-figures 32a and 38, 4

*Limnocythere sancti-patricii* BRADY and ROBERTSON, 1869, Ann. Mag. Nat. Hist., ser. 4, vol. 3, p. 17, pl. 18, figs 8–11; pl. 21, fig. 4. BRADY, CROSSKEY and ROBERTSON, 1874, Mon. Post.-Tert. Entomostraca, Paleontogr. Soc., p. 174, pl. 2, figs. 1–3. BRADY and NORMAN, 1889, Roy. Dublin Soc. Sci. Trans., vol. 4, ser. 2, p. 171, pl. 17, figs. 1, 2.

Female shell elongate-subquadrate in side view, hinge margin slightly curved, about three-fourths shell length, with broadly obtuse cardinal angles; ventral margin concave medially; anterior margin broadly rounded, extended along anteroventral marginal bend; posterior margin more narrowly rounded, slightly extended below. Valves approximately equal in size. Shell convexity low, greatest ventromedially. Surface of each valve bears a median vertical sulcus that dies out ventrally about one-third distance from ventral margin; anterior flank of sulcus steeper than opposing flank and bears two short, weak spurs resulting in a sinuous outline of the sulcus. A slight expansion is present midventrally in each valve; posteroventral surface behind alae compressed. Anterior end of shell compressed. General surface reticulate.

Hinge of left valve consists of a long bar with dorsojacent rabbet shelf, and at each end of which is a small socket-like, elongate depression. Hinge of right valve consists of the long dorsal edge rabbeted on its inner side for reception of bar of left valve, and terminal, small, elongate teeth, whose axes are roughly continuous with the rabbet groove. Inner lamellae fairly broad, especially anteriorly, but poorly calcified and with inner margin coinciding with line of concrescence. Radial canals widely spaced. Muscle scar consists of a vertical row of four closely spaced spots lying in a position corresponding to median sulcus, together with two more anterior spots.

Male shells elongate-subquadrate; dorsally with small nodes on either side of sulcus and with a small oblique anterodorsal sulcus. Other features as in female shells.

Antennules with terminal podomere slender and elongate, bearing three setae; penultimate podomere with three dorsal setae of which the middle is the longest.

Length of female shell (Pl. 60, fig. 1a) 0.49 mm., height 0.26 mm., convexity 0.20 mm. Length of male right valve 0.56 mm., height 0.27 mm.

*Remarks.*—Although type specimens of this species have not been seen, the outline, nature of the median sulcus, ventral low alation and reticulate ornamentation furnish a comparison with *L. sanctipatricii*. *L*

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EXPLANATION OF PLATE 60

FIGS. *1a–f—Limnocythere sanctipatricii* Brady and Robertson. *1a*, Left side of a complete female shell. *1b*, Right side of a complete female shell. *1c*, Left valve interior of male. *1d*, Exterior of a poorly preserved male right valve. *1e*, Ventral view of a complete female shell. All ×50. All from San Antonio Bay, No. 136A. *1f*, Right valve exterior, ×75. San Antonio Bay, No. 92A. (p. 613)

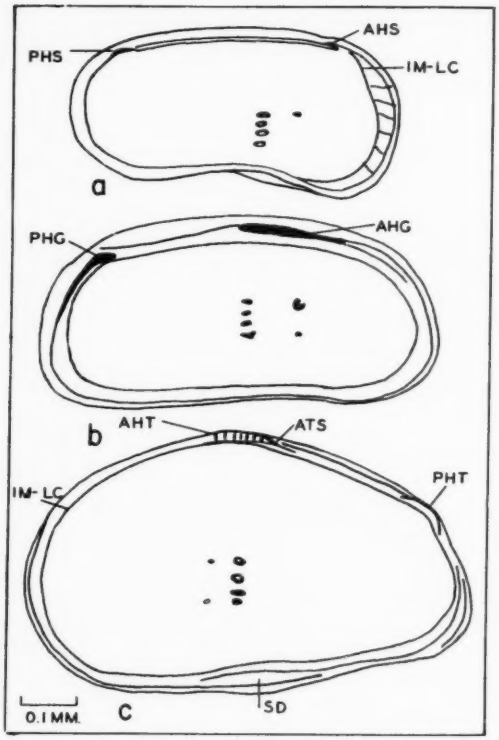
*2a–c—Limnocythere sanctipatricii* Brady and Robertson, var. A. *2a*, Left valve exterior of female? *2b*, Right valve exterior of male. *2c*, Exterior of immature left valve bearing a midventral, longitudinal ridge which is higher than in adult shells, ×75. San Antonio Bay, No. 92A. (p. 614)

*3a–c—Darwinula aurea* (Brady and Robertson). *3a*, Ventral view. *3b*, Right valve interior, ×50. San Antonio Bay, No. 92A. *3c*, Left side of a specimen in which a few of the appendages are retained, ×75. San Antonio Bay, No. 136A. (p. 610)

*4a–c—Potamocypris smaragdina* (Vavra). *4a*, Left side of a complete shell. *4b*, Left valve interior. *4c*, Left valve exterior. All are densely hairy on exterior valve surfaces, ×75. San Antonio Bay, No. 136A. (p. 605)

*5a, b—Physocypria pustulosa* (Sharpe). *5a*, Left valve interior. *5b*, Left valve exterior, ×75. San Antonio Bay, No. 136A. (p. 610)

*6a–c—Cypridopsis vidua* (Müller). *6a*, Left valve exterior. *6b*, Dorsal view. *6c*, Left valve interior. All are hairy and bear small closely spaced pits on exterior surfaces, ×75. San Antonio Bay, No. 136A. (p. 606)




TEXT-FIG. *32*—Outline drawing. a, *Limnocythere sanctipatricii* Brady and Robertson, interior of left valve, San Antonio Bay, No. 20A. b, *Hemicytherideis* sp., interior of left valve, San Antonio Bay, No. 32A. c, *Cyprideis torosa* (Jones), interior of right valve, San Antonio Bay, No. 136A. AHS, anterior hinge socket; PHS, posterior hinge socket; AHG and PHG, anterior and posterior hinge grooves; AHT, anterior hinge tooth; ATS, anterior triangular socket; PHT, posterior hinge tooth; IM, inner margin; LC, line of concrescence; SD, selvage discontinuity.

*verrucosa* Hoff (1942), a living species from Illinois, is much like *L. sanctipatricii* in shell characteristics, but is less elongate and apparently has stronger alation than *L. sanctipatricii*. The species has common distribution in Europe and North America. F. L. Staplin (written communication) believes the form under consideration is more coarsely pitted than is *L. sanctipatricii*.

*Occurrence.*—Figured specimens, San Antonio Bay, No. 136A. Frequent to abundant in the upper part of San Antonio Bay, particularly near front of Guadalupe River delta. Rare to frequent in middle, and at a few stations in lower part of bay and in samples from Matagorda Island.

### LIMNOCYTHERE SANCTIPATRICII Brady and Robertson variety A
### Plate 60, figures 2a–c

This form differs from the preceding in having the ventral margin relatively less concave and the ends more equally rounded. It has not yet been determined whether these variations are of sufficient importance to require taxonomic separation.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 96A.

### Subfamily CYTHERIDEINAE Sars, 1925

Shell ovate, subelliptical or subtrapezoidal; hinge margin typically curved and with taxodont articulation of the valves or rarely with the same structural hinge elements as typical cytherideids but lacking distinct taxodont crenulae, i.e., "*Cytherideis*" and *Cytherissa;* muscle scar contains two spots anterior to main vertical row of four spots. Triassic to Recent; marine, brackish and freshwater; worldwide distribution.

### Genus CYPRIDEIS Jones, 1856

*Anomocytheridea* STEPHENSON, 1938, Jour. Paleontology, vol. 12, p. 141 (Goerlich, 1952).

The genus was diagnosed by Goerlich (1952, p. 185) as follows:

Shell bean-shaped to trapezoidal; outer surface mostly covered with many small pits, accompanied occasionally by tubercles; pronounced sexual-dimorphism.

The hinge of *C. torosa* (Jones) as illustrated by Goerlich (op. cit., figs. 3a, 4) consists in the right valve of an anterior long, crenulate, raised dental area, a postjacent short crenulate groove, followed by a groove-like, depressed, crenulate, interterminal area, and a posterior raised crenulate area. The left valve hinge is the antithesis. Type species, *Candona torosa* Jones; Tertiary to Recent; worldwide distribution.

*Remarks.*—The hinge structure of *Anomocytheridea* as described by Stephenson (1938, p. 137) is the same as that of *Cyprideis* according to Goerlich (1952, p. 186). In the present material there is variation in the

interterminal segment of the hinge that results in its being more distinctly groovelike in *C. littoralis* and *C. locketti* but formed into a bar with faint crenulate incision in *C. torosa*. Whether these differences are of generic value is questionable, and the writer follows Goerlich in placing *Anomocytheridea* in synonymy.

CYPRIDEIS LOCKETTI (Stephenson)

Plate 59, figures 10a–c; Plate 64, figure 13

*Cytheridea locketti* STEPHENSON, 1936, La. Dept. Cons., Geol. Bull. 6, pp. 193, 196, pl. 5, figs. 10–13.

*Anomocytheridea locketti* (Stephenson), STEPHENSON, Jour. Paleontology, 1938, vol. 12, p. 143, pl. 23, figs. 1, 4, 7, 8.

Shell of male? subovate-acuminate in side view, highest medially to anteromedially; dorsal margin gently convex; ventral margin very slightly convex and gently sinuous; anterior margin broadly rounded, passing with abrupt curvature into ventral margin, but merging gradually with dorsal margin; posterior margin more narrowly rounded, strongly extended below. Left valve longer than right; extending beyond the other around entire periphery, with greatest extension along dorsal and ventral margins. Valves rather compressed, with greatest convexity in middle of posterior half and dorsad of midheight. Exterior surface of each valve bears a shallow, broad, anterodorsal vertical sulcus which extends to or slightly ventrad of midheight; anterior border and anteroventral portions of shell compressed and provided with a very narrow, low marginal rim within which, anteriorly, there is a second low rim. General surface ornamented by pits of varying size, the larger pits tending to occur in posterodorsal portion of shell. Weak, subvertical riblets occur in and behind median sulcus on some specimens.

Shell of female is shorter, more subquadrate, more equal ended and more convex than male.

Hinge of right valve consists of an anterior, long, elevated, dental area bearing about 15 crenulations, a postjacent short subtriangular socket lying approximately at midlength, a long interterminal depressed area consisting of simple valve edge and marked by a very weak, apparently noncrenulate longitudinal incision, and a posterior raised dental area bearing about six denticles. Hinge of left valve consists of an anterior elongate, depressed crenulate dental groove or socket, a postjacent short triangular tooth-like process formed where valve-edge bifurcates around margins of anterior socket, the long interterminal slightly raised valve edge which slightly overlaps corresponding edge of right valve, and a posterior crenulate, elongate socket. Muscle scar is an anteromedian vertical row of four closely spaced spots, with two more anterior spots. Inner lamellae broadest anteriorly; line of concrescence and inner margin almost coincide. Radial canals numerous and closely spaced around entire free margin. Right valve bears a prominent selvage ridge and adjacent marginal rabbet-groove for reception of overlapping left valve.

Length of a figured specimen (Pl. 59, fig. 10b) 1.06 mm., height 0.6 mm., convexity 0.49 mm.

*Remarks.*—The general shape, surface ornamentation and terminal compressed areas which Stephenson (1938, p. 143) termed "flanges" ally this species with *Cyprideis locketti* (Stephenson).

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 136A. Common to abundant in upper bay near front of Guadalupe Delta and in marshes on Matagorda Island; rare to frequent at scattered stations along eastern side of bay. It seems to be absent along the western side of the bay. The influence of the river perhaps is significant here. The species was described from the upper Miocene of Florida (*Potamides matsoni* zone).

CYPRIDEIS LITTORALIS Brady

Plate 59, figures 11a–c; Text-figures 38, 5a,b

*Cyprideis littoralis* BRADY, 1869, Nat. Hist. Trans. Northumb. and Durham, vol. 3, p. 1.

*Cytheridea torosa littoralis* (Brady), MÜLLER 1912, Das Tierreich, Ostracoda, p. 326.

*Cytheridea torosa* var. *teres* BRADY and NORMAN, 1889, Trans. Roy. Dublin Soc., vol. 4, ser. 2, p. 175.

*Cyprideis littoralis* Brady, SARS, 1928, Crust. Norway, p. 155, pl. 71, pl. 72, fig. 1. (Followed by other authors in recent years).

Shell subelliptical in side view; highest

medially; dorsal margin gently convex; ventral margin nearly straight to very slightly concave; terminal margins broadly and uniformly rounded, the anterior somewhat the broader. Left valve a little larger than right on the basis of marginal structures, but complete shells were not observed. Valves compressed in immature shells, moderately convex in adults, greatest convexity posterior half.

Slightly anterior to valve middle and occupying dorsal half is a narrow, shallow sulcus; anterior to which in young specimens are a small node and pit; posterior half of shell coarsely pitted.

Hinge of right valve consists of an anterior long, raised, crenulate dental area, an intermediate grooved dental area beginning posterad of midlength with a short triangular socket, followed by a very narrow groove which is bounded ventrally by the flangelike extension of valve edge that projects gradually farther outward toward rear to posterior end of hinge, where it rises to form an elongate crenulate, tooth-like elevation. Hinge of left valve not seen. Muscle scar consists of an anteromedian vertical row of four small, rounded spots, and two additional spots anterad of the main group. Inner lamellae broadest anteriorly; line of concrescence and inner margin nearly coincide. Radial canals numerous, occurring around entire free margins, showing some tendency to occur in pairs.

Antennules each consisting of four podomeres, the proximal one bearing one dorsal and two ventral setae, the second podomere having a single long seta; and the fourth podomere bearing a ventral seta at the proximal end and three long distal setae. Feet consisting of three podomeres, the first bearing a long seta; terminus with a long anteriorly curving claw.

Length of a large right valve (Pl. 59, fig. 11c) 0.80 mm., height 0.43 mm., convexity 0.16 mm.

*Remarks.*—This species is close to *Cyprideis littoralis* Brady in outline, dorsomedian sulcus, hingement and relatively small muscle scar. It is somewhat more coarsely pitted than seem typical for *C. littoralis.*

*Occurrence.*—San Antonio Bay, No. 16A. Rare to common at scattered localities in middle and lower parts of bay. Commonly found in nearshore or brackish waters in Europe, Asia and northern Africa.

### CYPRIDEIS TOROSA (Jones)

Plate 59, figures, 8a,b; Text-figure 32c

*Candona torosa* JONES, 1850, Ann. Nat. Hist. ser. 2, vol. 6, p. 27, pl. 3, figs. 6a-3.
*Cyprideis torosa* (Jones), JONES, 1856, Paleontogr. Soc. Mon., p. 21, pl. 2, figs. 1a-i, text-fig. 2.
*Cytheridea torosa* (Jones) MÜLLER, 1912, Das Tierreich, p. 326.
*Cyprideis torosa* (Jones), GOERLICH, 1952, Senckenbergiana, vol. 35, p. 186, figs. 1-5. Synonymy not complete.

Shell subpyriform in side view, highest medially to somewhat anteromedially; dorsal margin moderately convex, very obtusely angulated at position of greatest height; ventral margin slightly convex to somewhat sinuous; anterior margin broadly and uniformly rounded; posterior margin much more narrowly rounded, strongly extended, subacuminate below, truncate above. Left valve slightly larger than right, overlapping around free margins. Valves moderately convex, greatest convexity about one-third from posterior end.

Each valve bears a weak vertical dorsomedian sulcus; in well preserved specimens there is occasionally a second weak sulcus anterior to the other; posterior to sulcus in most specimens is a rounded, low, node-like swelling; in some specimens, possibly male dimorphs there is a small postero-midventral node or rounded swelling; in these same specimens, there may occur a third node-like swelling about one-fifth from posterior end of shell.

General surface finely pitted, with pitting generally strongest in midportion of valve. Anterior, and particularly anteroventral, margin bears a narrow, low rim; a similar low marginal rim forms a short subcaudate posteroventral rim in right valve, but this feature is much less conspicuous and may be absent in left valve.

Hinge of right valve consists of an anteromedian long, raised, crenulate, dental area, a postjacent short groove, a long very finely crenulate bar, formed of edge of valve but not extending to height of terminal dental areas, and a posterior short, crenulate, raised, dental area; dorsal to interterminal bar is a weakly developed rabbet-groove. Hinge of left valve consists of an antero-

median elongate, crenulate groove, a postjacent smooth short ridge, posterior to which valve edge is depressed and weakly crenulate, and passes toward rear into posterior elongate denticulate socket. Inner lamellae narrow, attaining only about 1/30 of shell length; line of concrescence and inner margin nearly coincide. Radial canals fairly numerous and occurring singly along anterior end, fewer posteriorly and ventrally. Muscle scar consists of a slightly anteromedian vertical row of four longitudinally elongate spots, with two additional spots anterior to main group, and possibly various other spots.

Length of a male? right valve (Pl. 59, fig. 8a) 0.79 mm., height 0.47 mm., convexity 0.21 mm. Length of a female? left valve (Pl. 59, fig. 8b) 0.75 mm., height 0.47 mm., convexity 0.21 mm.

*Remarks.*—This species resembles *Cyprideis torosa* (Jones) in shell outline, pitted surface, and possession of several node-like swellings on the surface. As described by Brady, Crosskey and Robertson (1874, p. 178) the species typically bears four rounded tubercles rather than three as in the present specimens. Some of the specimens described here bear few or no tubercles and thus resemble *C. torosa* var. *teres* (Brady and Robertson).

It is of interest to note Brady, Crosskey and Robertson's statement that the species is "usually an inhabitant of brackish water, where it is often found living in immense numbers, the situations which it haunts being chiefly salt marshes and muddy estuaries. It has, however, though very rarely, been found in quite fresh water, and more frequently in shallow littoral situations exposed to purely marine influences; but in neither of these latter cases does it ever occur very abundantly."

*Occurrence.*—Figured specimens from San Antonio Bay, No. 136A. Frequent to abundant at scattered stations in upper bay near front of Guadalupe Delta. Widespread in brackish environments in Europe, also found in Quaternary deposits of British Isles.

Genus HAPLOCYTHERIDEA Stephenson, 1936

*Cytheridea* (*Leptocytheridea*) [part] STEPHENSON, 1937, Jour. Paleontology, vol. 11, p. 156. (Stephenson, 1946)

*Cytheridea* (*Phractocytheridea*) SUTTON and WILLIAMS, 1939, Jour. Paleontology, vol. 13, p. 571. (Stephenson, 1946).

Subovate to subpyriform, moderately tumid, either left or right valve overlap; surface smooth, pitted or with median subvertical weak furrows; hinge of right valve with terminal raised crenulate dental areas and an interterminal, lower, crenulate bar. Type species, *Cytheridea montgomeryensis* Howe and Chambers, 1935. Marine; Cretaceous to Recent; worldwide occurrence.

HAPLOCYTHERIDEA BASSLERI Stephenson
Plate 59, figures 9a,b

*Cytheridea subovata* ULRICH and BASSLER, 1904, Maryland Geol. Surv., Miocene, p. 124, pl. 37, figs. 1–8.

*Cytheridea* (*Haplocytheridea*) *subovata* (Ulrich and Bassler) STEPHENSON, 1938, Jour. Paleontology, vol. 12, p. 134, pl. 23, fig. 23; pl. 24, figs. 9, 10; text-figure 3.

*Cytheridea bassleri* STEPHENSON, 1943, ibid., vol. 17, p. 206.

This species exhibits dimorphic features, the male and the immature shells being more pointed posteriorly and more umbonate dorsally than the female shells. Female shell described below.

Outline subovate, highest medially; dorsal margin moderately convex; ventral margin slightly convex; terminal margins broadly and nearly equally rounded, the posterior truncate medially and the anterior slightly extended below. Left valve larger than right and overlapping it. Valves rather strongly convex, with greatest convexity just behind middle.

Surface of each valve bears two weak short sulci in an anterodorsal position, but not reaching dorsal margin; the more anterior of the two is somewhat curved. General surface bears scattered pits with width of interspaces varying from about the diameter of the pits to several times this diameter; pits become sparser along the margins in adult specimens. Anterior margin and in some specimens posteroventral margin bear very narrow low marginal rims.

Hinge of left valve consists of an anterior elongate, crenulate, denticulate socket, lying approximately in position of greatest height of shell, an interterminal faintly crenulate groove set in the barlike edge of valve, and a posterior long crenulate socket;

dorsal to interterminal bar occurs a poorly defined rabbet-groove or accommodation groove. Hinge of right valve not observed. Inner lamellae narrow, with line of concrescence and inner margin slightly separated. Radial canals not clearly observed but apparently are rather widely spaced.

Length of a left valve (Pl. 59, fig. 9b) 0.98 mm., height 0.64 mm., convexity 0.30 mm.

*Remarks.*—Although *Haplocytheridea bassleri* was described by Ulrich and Bassler from the Miocene, the present specimens seem so closely related to that species in the ovate outline of the adult, surface pitting and weak dorsomedian sulci, that they are here referred tentatively to it.

*Occurrence.*—Figured specimens, San Antonio Bay, No. 36A, No. 45A. Rare to abundant at scattered stations in lower part of bay and in marshes on Matagorda Island. The species has been obtained previously from the Calvert formation, middle Miocene of Maryland; and from the Miocene of Florida and North Carolina.

HAPLOCYTHERIDEA BRADYI (Stephenson)
Plate 59, figures 12a,b

*Cytheridea* (*Haplocytheridea*) *bradyi* STEPHENSON, 1938, Jour. Paleontology, vol. 12, p. 129, pl. 23, fig. 22; pl. 24, figs. 5, 6; text-fig. 10.

Striking dimorphism is present in the shells of this species. the males are much more elongate and lanceolate than are the females. The immature molts on the other hand resemble neither of the adults in outline, being more triangular in shape. The female shell will be described below.

Shell subovate in side view highest medially, with postdorsal slope truncate; dorsal margin moderately convex, weakly umbonate medially; ventral margin slightly convex; terminal margins broadly rounded, the anterior extended below, the posterior very slightly extended below. Right valve larger than left, overlapping it. Valves moderately convex, with greatest convexity slightly postmedian. The surface ornamented by many large, deep, widely spaced pits.

Hinge of right valve is formed of an anterior elongate, crenulate socket, an interterminal and posteromedian bar bearing along its crest a minutely denticulate groove and a posterior denticulate and crenulate socket. Hinge of left valve consists of terminal elongate crenulate teeth and a very narrow interterminal crenulate bar which fits into corresponding very narrow groove in the interterminal bar of right valve. Inner lamellae of moderate width anteriorly, narrower elsewhere; line of concrescence and inner margin slightly separated. Radial canals not clearly observed but apparently numerous. Right valve bears a prominent selvage groove, and left valve a corresponding selvage ridge along free margin.

Length of female right valve (Pl. 59, fig. 12a) 0.70 mm., height 0.44 mm., convexity 0.19 mm. Length of a male left valve (Pl. 59, fig. 12b) 9.74 mm., height 0.38 mm., convexity 0.18 mm.

*Remarks.*—This species is distinguished by the prominent right valve overlap, reversal of hinge teeth and sockets compared to normal *Haplocytheridea* and by its general shape and ornamentation. The present specimens are evidently the same as Stephenson's material from the Caloosahatchee marl, Pliocene of Florida, except that the faintly "granular" surface appearance between the pits in Stephenson's specimens was not observed here.

*Occurrence.*—Figured specimens, San Antonio Bay, No. 35A. Rare to common in lower bay and Matagorda Island marshes. The species was originally described from the Pliocene Caloosahatchee marl of Florida (Stephenson, 1938, p. 132).

Genus PERISSOCYTHERIDEA Stephenson, 1938

Shell subpyriform; hinge margin nearly straight, anterior margin broadly rounded; posterior narrowly rounded to pointed; left valve slightly the larger, surface bears pits, reticulation or weak ridges; may be weakly alate ventrally. Hinge consists in right valve of terminal elongate, crenulate, slightly elevated dental areas separated by a weakly incised line of crenulations. Hinge of left valve the antithesis. Type species, *Cytheridea? matsoni* Stephenson, 1935. Miocene to Recent; Gulf Coast region. *Hutsonia* Swain of the Upper Jurassic of Louisiana may lie in the same ancestral lineage, and there is a similar, perhaps undescribed genus in the marine subsurface Lower Cretaceous of Maryland.

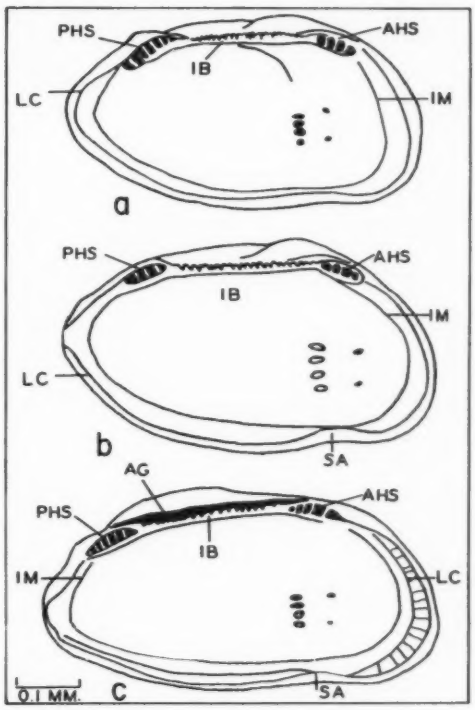
PERISSOCYTHERIDEA BRACHYFORMA Swain, n. sp.

Plate 61, figures 1a–e, 2a–e, (molts) 5a–g (late instar valves and adults); Text-figures 33a and 39, 6a–c

Shell subquadrate-acuminate in lateral view; greatest height about three-eighths from anterior end; dorsal margin nearly straight in left valve, sinuous in right, slightly more than half of shell length; ventral margin nearly straight in left valve, slightly convex in right, but weakly concave anteromedially in both valves; anterior margin broadly rounded, extended below, truncate above; posterior margin narrowly and subacuminately rounded, strongly extended medially, slightly concave above. Left valve larger than right, overlapping and extending beyond right most noticeably along dorsal slopes and midventrally. Valves moderately convex with greatest convexity in a postero-mid-dorsal position.

A short oblique groove or sulcus lies in an anteromedian position near cardinal angle; immediately posterior to sulcus, posterodorsal surface of valve swollen and in most specimens extends slightly beyond dorsal margin; this surface bears four slightly sinuous, narrow, longitudinal ridges, of varying height, the more dorsal pair joined anteriorly by a weak crossridge. The more ventral three ridges have a row of pits between each two of them; midventrally surface bears a low alaform ridge, which varies considerably in degree of development, but in well preserved specimens is highest posteriorly and terminates in a point, anteriorly it merges more gradually with general surface. Anterior border and subcaudate portion of posterior border compressed to form narrow flattened marginal rims.

Hinge of right valve consists of very narrow, terminal, elevated, crenulate teeth, and an interterminal slightly incised line of tiny crenulations. Hinge of left valve composed of terminal elongate crenulate sockets separated by a high interterminal crenulate bar, formed of extended edge of valve, and in which the crenulations occur most prominently along dorsal portion of bar; dorsal to bar is an accommodation groove for dorsal edge of right when valves are




TEXT-FIG. *33*—Outline drawings. a, *Perissocytheridea brachyforma*, n. sp., interior of left valve, San Antonio Bay, No. 16A. b, *Perissocytheridea brachyforma excavata*, n. subsp., interior of left valve, San Antonio Bay, No. 26A. c, *Perissocytheridea rugata*, n. sp., interior of left valve, San Antonio Bay, No. 26A. AHS and PHS, anterior and posterior hinge sockets; IB interterminal hinge bar; AG, accommodation groove; IM, inner margin; LC, line of concrescence; SA, selvage apophysis.

open. Inner lamellae fairly broad in mature shells; line of concrescence and inner margin slightly separated. Radial canals few and widely spaced. Free margin of left valve bears a selvage groove to receive edge of right.

Antennule with the distal three podomeres of equal length but gradually tapering; second and penultimate podomeres each with a long dorsal seta; ultimate podomere with three very long and slender, perhaps natatory, setae. Endopodite portion of antenna apparently with only two podomeres, the distal one very long; proximal podomere with exopodite flagellum extending slightly beyond tip of antenna; distal podomere with

two strong, sharply curved terminal claws. Legs bear a single very long terminal claw.

Length of a figured right valve (Pl. 61, fig. 5a), probably a late instar valve, 0.50 mm., height 0.27 mm., convexity 0.15 mm. Length of holotype (Pl. 61, fig. 5b) 0.50 mm., 0.29 mm., convexity 0.28 mm.

*Relationships.*—It is very difficult to distinguish among the molts of several of the species of *Perissocytheridea* in this collection, but nearly all the molts of the genus at every locality apparently belong in *P. brachyforma*, or to a subspecies of it. The subspecies of *P. brachyforma* recognized here is discussed below. The ridge pattern and ventral weak alation characterize the species. Individual variation is very great in the species so that more than one subspecies may eventually be recognized.

*Occurrence.*—This is the most abundant species in San Antonio Bay, reaching greatest frequency slightly west of the middle of the bay. The figured specimens are from stations 3, 6, 10, 12, 16, 22 and 41. The holotype is from station 41.

PERISSOCYTHERIDEA BRACHYFORMA EXCAVATA Swain, n. subsp.

Plate 62, figures 1a–c; Text-figure 33b

Shell subpyriform in side view; greatest height slightly less than one-third from anterior end; dorsal margin nearly straight, but slightly sinuous and approximately two-thirds of shell length; ventral margin somewhat convex, converging with the dorsum toward posterior end, anterior margin broadly rounded, extended below and subtruncate above; posterior margin narrowly rounded to acuminate with a slightly dorsomedian short caudal process; dorsad of caudal process, margin slightly concave in most specimens. Left valve somewhat larger than right, but overlap relationships not clearly seen. Valves moderately convex with greatest convexity posteromedian.

A shallow, narrow sulcus lies in an anterodorsal position; it begins just beneath anterocardinal angle and extends approximately to mid-height. In the holotype, surface immediately posterior to sulcus is elevated as a broad rounded swelling. Several sinuous longitudinal ridges occupy approximately middle half of valve, all of which tend to converge in a posterior direction; of these, the ventral one begins about one-fourth from anterior end, extends posteriorly to about one-third from end where it curves abruptly dorsally and anteriorly as a hooked-shaped loop; the other longitudinal ridges are irregularly distributed, in some specimens two of the subdorsal ridges are connected posteriorly.

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EXPLANATION OF PLATE 61

FIGS. *1a–e—Perissocytheridea brachyforma* Swain, n. sp. All male specimens. *1a, c*, Exterior view of two male right valves, ×75. San Antonio Bay, No. 41A. *1b*, Exterior of an immature right valve, ×75. San Antonio Bay, No. 3A. *1d*, Interior of an immature right valve, ×75. San Antonio Bay, No. 41A. *1e*, Exterior of an immature, weakly ornamented right valve, ×75. San Antonio Bay, No. 3A. (p. 619)

*2a–e—Perissocytheridea brachyforma* Swain, n. sp. Female paratype specimens. *2a*, Right side of an immature shell, ×75. San Antonio Bay, No. 6A. *2b*, Exterior of a left valve, ×75. San Antonio Bay, No. 41A. *2c, d*, Exterior of an immature right valve and an adult left valve, ×75. San Antonio Bay, No. 6A. *2e*, Right side of a complete shell ×75. San Antonio Bay, No. 41A. (p. 619)

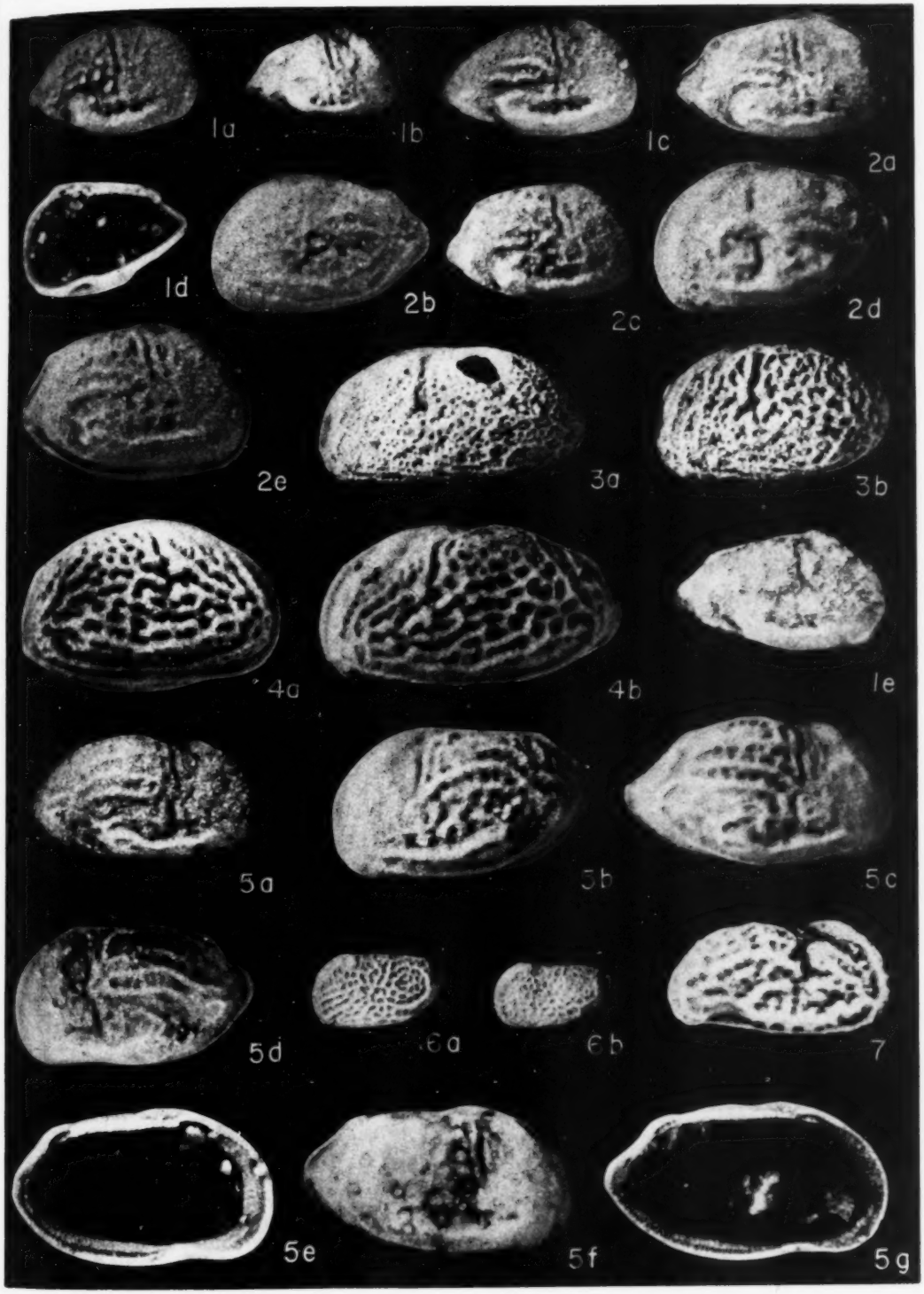
*3a, b—Perissocytheridea bicelliforma* Swain, n. sp. *3a*, Exterior of holotype, a left valve. *3b*, Exterior of paratype immature left valve. Both female?, ×75. San Antonio Bay, No. 6A. (p. 621)

*4a, b—Perissocytheridea rugata* Swain, n. sp. *4a*, Right side of holotype, a male shell, ×50. San Antonio Bay, No. 26. *4b*, Exterior of a female paratype left valve, ×75. San Antonio Bay, No. 35A. (p. 622)

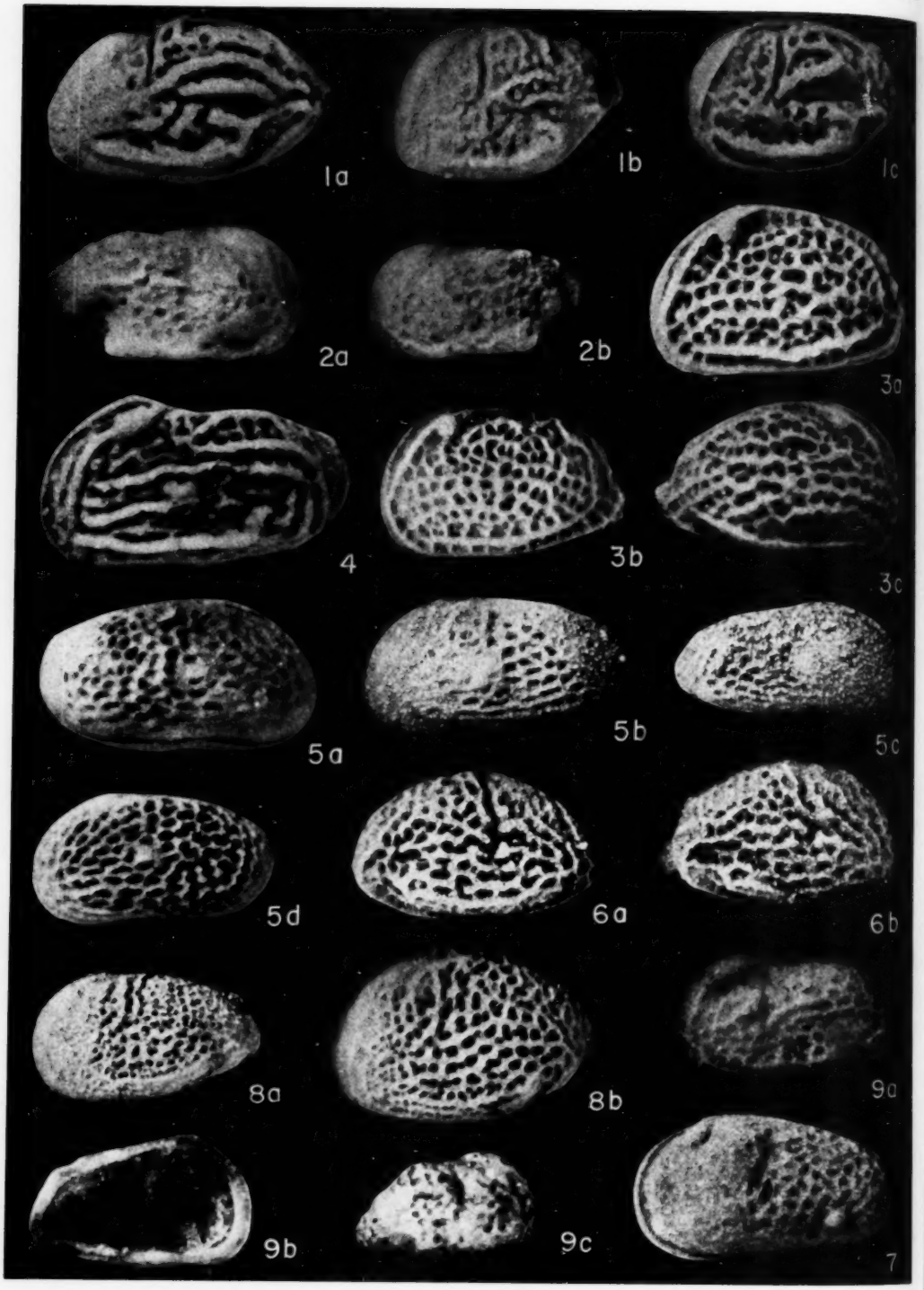
*5a–g—Perissocytheridea brachyforma* Swain, n. sp. *5a*, Exterior of an immature paratype right valve, ×75. San Antonio Bay, No. 12A. *5b*, Left side of holotype, ×75. San Antonio Bay, No. 10A. *5c*, Exterior of a paratype right valve, ×75. San Antonio Bay, No. 22. *5d–g*, Left side, left valve interior, right side, and left valve interior respectively, of four paratype specimens, ×75. San Antonio Bay, No. 16. (p. 619)

*6a, b—Monoceratina?* sp. Exterior views of two immature left valves, ×75. San Antonio Bay, No. 3A. (p. 637)

*7—Paracytheridea troglodyta* Swain, n. sp. Exterior of holotype, a right valve, ×75. San Antonio Bay, No. 26. (p. 623)




Swain, Texas Recent ostracodes




Swain, Texas Recent ostracodes

Valve surface between ridges is erratically pitted.

Hinge of left valve consists of terminal elongate, crenulate sockets, separated by a long bar which is weakly crenulated and dorsad of which is a broad accommodation groove. Hinge of right valve not seen. Inner lamellae of moderate width, line of concrescence and inner margin slightly separated anteriorly. Radial canals few, simple and widely spaced. Muscle scar not observed because of filling of shells by matrix.

Length of holotype, left valve (Pl. 62, fig. 1a) 0.53 mm., height 0.33 mm., convexity 0.17 mm.

*Relationships.*—The holotype of this subspecies closely resembles typical *Perissocytheridea brachyforma*, n. sp., in shape, dorsal median swelling and in possessing several sinuous longitudinal ridges in middle portion of shell. The ridges, however, in the subspecies *P. brachyforma excavata* are generally much stronger than in the typical form, and the ventral ridge forms a characteristic hook-shaped loop near its posterior end.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 26. The species was found at one station in the upper bay near Guadalupe Delta; otherwise it is rare to common at scattered stations in the lower bay and rarely on Matagorda Island and in the open Gulf.

### PERISSOCYTHERIDEA BICELLIFORMA Swain, n. sp.

Plate 61, figures 3a, b; Plate 64, figure 4

Shell elongate-ovate in lateral view; highest about one-third from anterior end; dorsal margin somewhat sinuous, in general slightly convex; ventral margin nearly straight to sinuous, in general converging toward posterior with respect to dorsum; anterior margin broadly rounded, strongly extended anteroventrally, subtruncate anterodorsally, posterior margin more narrowly rounded, extended medially. Valves nearly equal in size, the left slightly larger; moderately to strongly convex, the relatively elongate males being somewhat more compressed than females, greatest convexity about one-third from posterior end, and in ventral half, producing in that region a broad flat to slightly overhanging venter. Each valve bears a slightly anteromedian short groove extending from near dorsal margin, approximately to midheight; posterodorsal surface behind median groove more or less swollen, in some specimens projecting

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### EXPLANATION OF PLATE 62

FIGS. *1a–c—Perissocytheridea brachyforma excavata* Swain, n. subsp. *1a*, Exterior of holotype. *1b*, Exterior of immature paratype, left valve having rather weak surface ornamentation. *1c*, Exterior of more strongly ornamented paratype, left valve, ×75. San Antonio Bay, No. 26. (p. 620)

*2a, b—Paracytheridea vandenboldi* Puri. *2a*, Right valve exterior. *2b*, Exterior of left valve, ×75. San Antonio Bay, No. 30. (p. 625)

*3a–c—Hemicythere conradi* Howe and McGuirt. *3a*, Left valve exterior. *3b*, Right valve exterior. *3c*, Exterior of immature left valve, ×75. San Antonio Bay, No. 22. (p. 635)

*4—Paracytheretta multicarinata* Swain, n. sp. Exterior of holotype, a left valve, ×75. San Antonio Bay, No. 35A. (p. 636)

*5a–d—Campylocythere concinnoidea* Swain, n. sp. *5a*, Right side of holotype, a complete female shell. *5b*, Exterior of paratype male? left valve. *5c*, Right side of immature paratype shell. *5d*, Left side of immature paratype shell, ×75. *5a, d*, San Antonio Bay, No. 35A. *5b, c*, San Antonio Bay, No. 10. (p. 636)

*6a, b—Perissocytheridea rugata* Swain, n. sp. Exteriors of two immature paratype left valves, ×75. San Antonio Bay, No. 109A. Compare with adult male and female shells, Pl. 61, figs. *4a, b*. (p. 622)

*7—Leptocythere paracastanea* Swain, n. sp. Left side of a female? shell, ×75. San Antonio Bay, No. 16. (p. 640)

*8a, b—Perissocytheridea bicelliforma* var. *propsammia* Swain, n. var. *8a*, Exterior of an immature left valve, ×75. San Antonio Bay, No. 114A. *8b*, Left valve exterior, the holotype, ×75. San Antonio Bay, No. 114A. (p. 622)

*9a–c—Paracytheridea troglodyta* Swain, n. sp. *9b*, Interior of paratype male left valve. *9a*, Left side of holotype female shell. *9c*, Exterior of immature paratype right valve, ×75. San Antonio Bay, No. 54A. (p. 623)

slightly beyond dorsal margin; general surface in well preserved specimens coarsely reticulated; several weak ridges more or less parallel to margins of valve occur anteriorly and ventrally; a set of smaller surface pits is present to a greater or lesser degree of development in the depressions between the reticulating ridges; some specimens have the reticulating ridges abraded or poorly developed so that the smaller pits are more prominent; other specimens have stronger reticulations and the small pits are barely visible.

Hinge of left valve consists of terminal elongate sockets each bearing five or six denticles, separated by a finely crenulate bar, dorsad of which is a sloping accommodation groove. Hinge of right valve consists of terminal raised, elongate crenulate ventral areas and an interterminal rabbet-groove which opens into valve interior. Inner lamellae of moderate width, broadest anteriorly; line of concrescence and inner margin considerably separated, the breadth of this separation and of the marginal zone each equalling about .056 of shell length. Muscle scar situated just anterad of lower portion of inner transverse ridge that marks position of external median groove; it consists of four longitudinally-elongate, closely spaced spots and two additional more anterior spots. Normal canals are few and widely spaced and are represented by rather large pits on interior valve surface. Radial canals not clearly seen, but apparently are numerous and closely spaced anteriorly.

Length of holotype (Pl. 61, fig. 3a) 0.51 mm., height 0.27 mm., convexity 0.14 mm., length of paratype (Pl. 61, fig. 3b) 0.45 mm., height 0.28 mm., convexity 0.16 mm.

*Remarks.*—This species is distinguished by the two sizes of surface reticulation and pitting. The surface ornamentation, shape, degree of posterodorsal swelling, and strength of anterior and ventral concentric ridges all are extremely variable in this species.

*Occurrence.*—Holotype and paratype from San Antonio Bay, No. 6A. Scattered occurrence varying from rare to abundant at stations in marginal parts of bay and on Matagorda Island.

PERISSOCYTHERIDEA BICELLIFORMA var. PROPSAMMIA Swain, n. var.

Plate 62, figures 8a,b

This variety is similar to the shorter, presumably male, dimorphs of *P. bicelliforma*, but is even higher with respect to length, has the dorsal margin more strongly arched and in most instances a more heavily calcified shell. There is also a very weak postventral alate swelling not seen in typical *P. bicelliforma*.

Length of holotype, a left valve, 0.52 mm., height 0.35 mm., convexity 0.17 mm. (Pl. 62, fig. 8b).

*Remarks.*—This variety is difficult to separate from typical *P. bicelliforma*, but the above characteristics seem to hold true for specimens found around the margins of the bay and in the barrier island marshes, where the substrate is typically sandy rather than clayey. Because of uncertainty as to identification of it in many cases, it has not been plotted separately as to distribution. The distribution of the species is not especially distinct from that of typical *P. bicelliforma* so it is not here considered as a geographic subspecies but only a variety. It may possibly occupy some ecologic niche which excludes *P. bicelliforma* s.s., and as such would probably be a subspecies.

*Occurrence.*—Figured specimens from San Antonio Bay, Nos. 114A and 144A.

PERISSOCYTHERIDEA RUGATA Swain, n. sp.

Plate 61, figures 4a,b; Plate 62, figures 6a,b; Text-figure 33c

Shell of variable elongation, presumed male specimens are relatively short and high with respect to females; outline subovate, ratio of length to height in presumed male specimens approximately 8 to 5, that in females approximately 9 to 5; greatest height slightly anteromedian; dorsal margin moderately convex, in males strongly truncate behind position of greatest height, in females sinuous behind that position; ventral margin slightly convex, somewhat sinuous and anteriorly; anterior margin broadly rounded, rather prominently extended anteroventrally and subtruncate above; posterior margin much more narrowly rounded, strongly extended as a short subcaudal process below, turncate above.

Left valve larger than right, overlapping and extending beyond the other terminally and anterodorsally; ventrally there is left valve overlap, but ventral surfaces of both valves overhang ventral margin. Valves strongly convex with greatest convexity midventral in both dimorphs, and secondarily strong posterodorsally in female specimens.

Slightly anterior to midlength in each valve is a narrow rather weak groove extending from near dorsum approximately to mid-height; behind this groove in female specimens posterodorsal surface more or less swollen, and extending beyond dorsal margin; strongly inflated ventral median portion of each valve bears a weakly developed alate structure that terminates behind about a fourth distance from posterior end; posterior to this termination in most specimens there is a curving very narrow elevated ridge, which together with the short alae mentioned above provides a doubly though weakly alate appearance to the valve. Ventrally in both dimorphs and anteriorly as well in males there are several weak concentric ridges roughly parallel to margin. General surface of valves ornamented by coarse reticulations, but with the reticulating ridges so sinuous as to provide no regularity to the shape of the interspaces.

Hinge of left valve consists of terminal elongate crenulate sockets each of which apparently pass with little interruption into the broad selvage groove of free margins, and an interterminal raised crenulate bar and associated accommodation groove. Hinge of right valve consists of terminal elongate denticulate teeth separated by a crenulate rabbet-groove which is overhung by mid-dorsal origin. Inner lamellae fairly broad; line of concrescence and inner margin separated; lamellae with faint concentric lines. Radial canals few and simple. Muscle scar is typical of other species of the genus.

Length of holotype, a male shell, 0.51 mm., height, 0.32 mm., convexity 0.31 mm.

*Relationships.*—The ventrally extended, truncate posterior margin and narrow alaform ventral ridges distinguish this species from *P. bicelliforma* var. *propsammia*, n. var., which it resembles in general shape and surface ornamentation. *Perissocytheridea matsoni* Stephenson of the Miocene is similar to *P. rugata* in shape but the surface pits are shallower and the ventral alae somewhat stronger than in *P. rugata*.

*Occurrence.*—The holotype is from San Antonio Bay, No. 26A; paratypes from 26A and 35A. Rare to abundant at stations in southeastern part of bay, locally rare to abundant in a few other scattered stations in bay and on Matagorda Island.

### Genus PARACYTHERIDEA Müller, 1894

Subpyriform, similar in general shape to, but typically more nodose and ventrally more alate than, *Perissocytheridea* Stephenson. Hinge consists, in right valve, of terminal elongate taxodont teeth and an interterminal serrate groove; in left valve interterminal area is a crenulate bar, with dorsally adjacent weak accommodation groove. Type species, *Paracytheridea depressus* Müller, 1894. Cretaceous?, Eocene to Recent; North America, Europe.

### PARACYTHERIDEA TROGLODYTA Swain, n. sp.

Plate 61, figure 7; Plate 62, figures 9a–c; Plate 64, figure 6; Text-figures 34a and 38, 6a–c

Outline of shell, subquadrate; highest about one-fifth from anterior end; dorsal margin sinuous, typically concave for a short distance medially, slightly more than two-thirds of shell length; ventral margin relatively straighter than dorsal but also sinuous, typically with a slight concavity near posterior end; anterior margin broadly rounded, extended medially to ventromedially and subtruncate above; posterior margin narrower, strongly extended below and sharply truncate above. Left valve slightly larger than right, extending beyond the right terminally. Valves compressed with greatest convexity in adults in posterior half.

Anterodorsally there are two short sulci extending ventrally and anteroventrally, respectively, from a place on dorsal margin just posterior to position of greatest height; a rounded bead-like node or lobe lies between the sulci just dorsal to midheight. Posterior to the more median sulcus, surface of valve elevated to form a postero-

dorsal swelling; in mature specimens this swelling extends approximately to posterior end. In adults the swelling extends rather strongly beyond dorsal margin (Pl. 61, fig. 7; Pl. 62, fig. 9a). In immature specimens, however, the swelling is much shorter, dies out about one-third from posterior end and there is a second nodelike swelling near posterior end (Pl. 62, fig. 9c). The ventral midportion of each valve bears a poorly defined ridge-like elevation which in some specimens terminates as a low node slightly more than one-third from posterior end; ventral surface posterior to this node rather strongly depressed. Anterior end bears a low broad ridge extending from anterocardinal angle to venter; in some specimens a low and more interior ridge rises approximately at midheight extends ventrally and posteriorly nearly to posterior end. General surface of each valve bears numerous large pits, the interspaces in the posterior half of the shell, in some specimens, raised to form low narrow ridges.

Hinge of right valve consists of an anterior elongate, slightly elevated, and weakly crenulate tooth, an interterminal weakly crenulate groove which is widest anteriorly and becomes progressively narrower toward posterior end, and a posterior elongate, crenulate tooth; both tooth structures represent continuations of the edge of the valve around cardinal angles; in posterior half, interterminal groove is overhung by valve margin. Hinge of left valve consists of terminal elongate crenulate sockets and an interterminal finely crenulate bar with dorsojacent poorly defined accommodation groove. Inner lamellae rather narrow, line of concrescence and inner margin well separated, especially anteriorly; radial canals few and widely spaced. Muscle scar not clearly seen, but apparently consists of a vertical row of three or four spots located on an inner transverse ridge that represents the external median sulcus.

Antennae consisting of two long stout podomeres (endopodite), the second one bearing distally a long dorsal exopodite flagellum, a ventral seta near distal end, and two strongly curved terminal claws. Mandibular palp of four podomeres, penultimate one with three setae, ultimate podomere strongly tapering and armed with two terminal setae. Respiratory plate of maxilliped with 11 or 12 flexible vibratory setae.

Length of holotype (Pl. 62, fig. 9a) 0.42 mm., height 0.23 mm., convexity 0.22 mm

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EXPLANATION OF PLATE 63

FIGS. *1a–c—Leptocythere paracastanea* Swain, n. sp. *1a*, Exterior of a male? nearly smooth, right valve. *1b*, Exterior of holotype, a male? left valve having delicately beaded, reticulate, surface ornamentation. *1c*, Exterior of a smooth male? right valve, ×75. *1a*, San Antonio Bay, No. 16; *1b*, No. 6A; *1c*, No. 90A. (p. 640)

*2a–c—Microcythere johnsoni* Mincher *2a*, Right side of an immature shell. *2b*, Right side of a female shell. *2c*, Left side of a male? shell, having appendages still projecting from between valves, ×75. *2a, c*, San Antonio Bay, No. 3A; *2b*, No. 22. (p. 641)

*3—Hemicytherideis* aff. *H. mayeri* (Howe and Garrett). Exterior of a left valve, ×75. San Antonio Bay, No. 109A. (p. 631)

*4—Cytheromorpha pascagoulaensis* Mincher Exterior of a right valve, ×75. San Antonio Bay, No. 74A. (p. 630)

*5a, b—Actinocythereis* aff. *A. exanthemata* (Ulrich and Bassler). *5a*, Exterior of an immature left valve, believed to represent the species. *5b*, Right valve exterior, ×75. *5a*, San Antonio Bay, No. 41A; *5b*, No. 6A. (p. 634)

*6a–d—Paradoxostoma atrum* Müller. *6a*, Interior of a left valve. *6b*, Exterior of an immature left valve. *6c*, Interior of a right valve. *6d*, Interior of a left valve, ×75. *6a*, San Antonio Bay, No. 12A; *6b*, No. 6A; *6c–d*, No. 16. (p. 632)

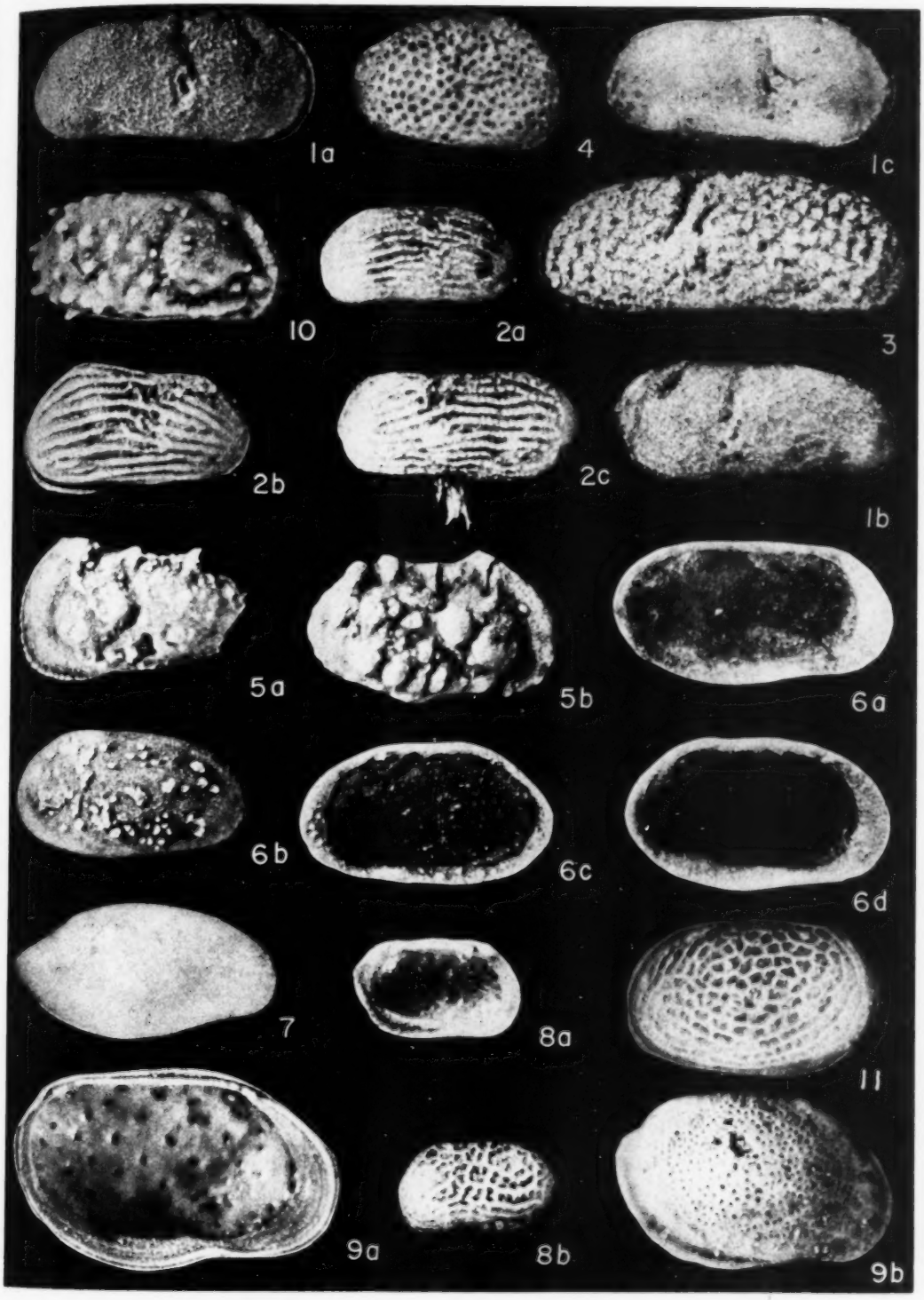
*7—Parodoxostoma ensiforme* Brady. Right side of a complete shell, ×75. San Antonio Bay, No. 37A. (p. 633)

*8a, b—Cytherura radialirata* Swain, n. sp. *8a*, Left valve interior. *8b*, Left side of holotype a complete shell, ×75. San Antonio Bay, No. 3A. (p. 626)

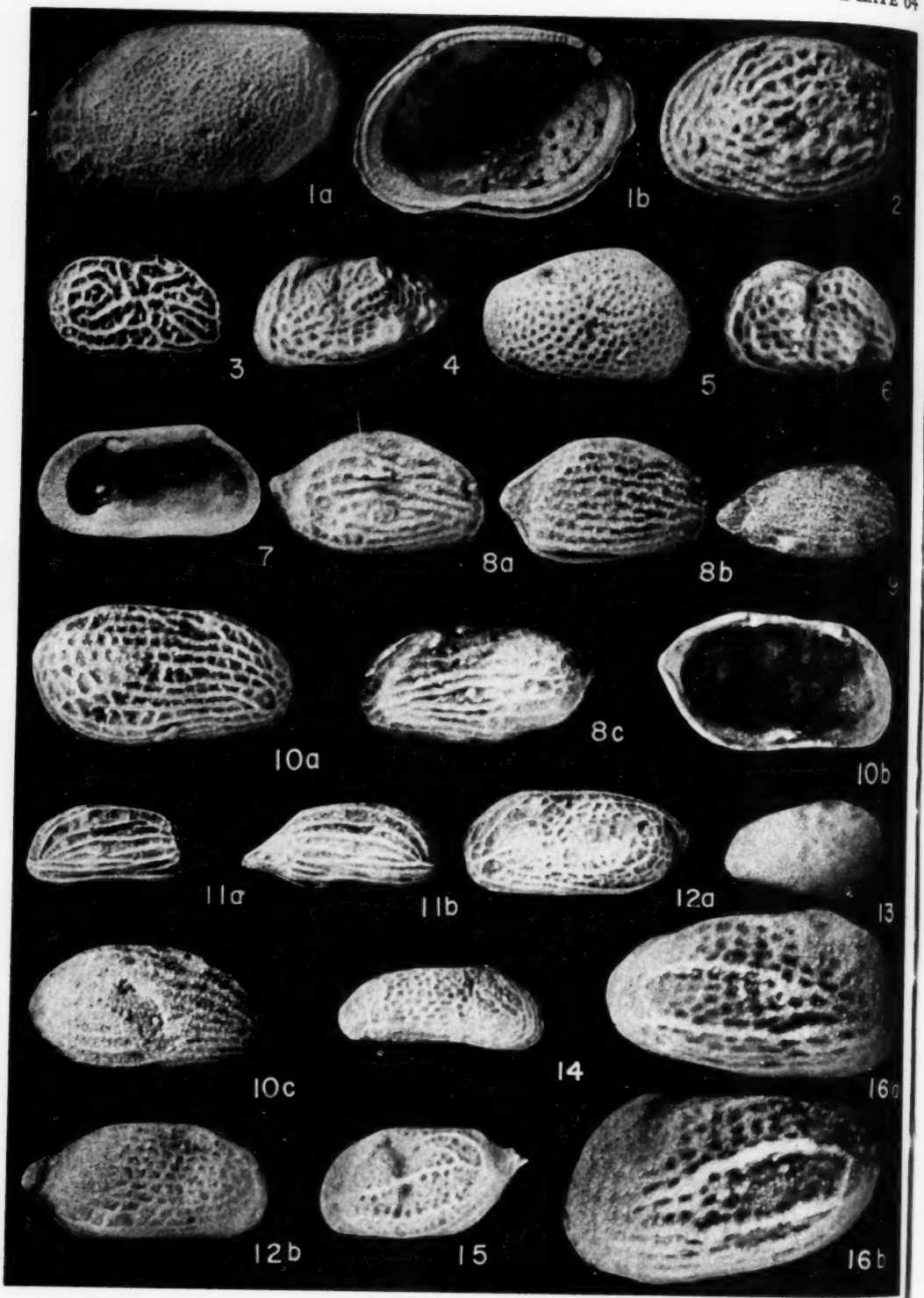
*9a, b—Loxochoncha matagordensis* Swain, n. sp. *9a*, Left valve interior. *9b*, Immature right valve exterior, ×75. San Antonio Bay, No. 22. (p. 629)

*10—Puriana* sp. Exterior of a right valve, ×75. Open Gulf, No. J31A. (p. 635)

*11—Loxochoncha australis* Brady. Exterior of a left valve, ×75. Open Gulf No. J36A. (p. 630)




Swain, Texas Recent ostracodes




Swain, Texas Recent ostracodes

*Relationships.*—The generic position of this species is somewhat uncertain. The general outline, sulcation, and posterodorsal swelling suggest a relationship to *Perissocytheridea*, but the compressed shell, the strong ventral alaform nodes in the immature specimens, and the strong compression of the posteroventral portion of the shell indicates a similarity to described species of *Paracytheridea*. The typical high ventral alae of *Paracytheridea*, however, are lacking in this species.

*Occurrence.*—The holotype is from San Antonio Bay, No. 54A. Rare to common at scattered stations in upper bay near delta front, and in middle bay; rare at a few stations in lower bay.

PARACYTHERIDEA VANDENBOLDI Puri
Plate 62, figure 2a,b

*Cytheropteron nodosum* ULRICH and BASSLER, 1904, Maryland Geol. Survey, Miocene, p. 129, pl. 38, figs. 37–40 [not *C. nodosum* Brady, 1868].

*Paracytheridea nodosa* (Ulrich and Bassler), HOWE and others, 1935, Florida Dept. Conserv., Geol. Bull. 13, p. 37, pl. 3, fig. 7.

*?Paracytheridea altila* EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 512, pl. 85, figs. 20, 21.

*Paracytheridea vandenboldi* PURI, 1953, Jour. Paleontology, vol. 27, p. 751.

The external characteristics of this species were descibed by Ulrich and Bassler (1904), and Howe, et al. (1935); the internal structures were partly described by Swain (1951). The following additional observations may be made on the internal structures. The inner lamellae are relatively narrow but the line of concrescence and inner margin are slightly separated. The present specimens from San Antonio Bay seem to be conspecific with those from the Tertiary. The species is quite variable particularly as to the strength of development of the alae.

*Occurrence.*—Figured specimens are from

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EXPLANATION OF PLATE 64

FIGS. *1a, b—Loxoconcha matagordensis* Swain, n. sp. *1a*, Exterior of left valve. *1b*, Interior of right valve, ×75. San Antonio Bay, No. 193A. (p. 629)

*2—Loxoconcha australis* Brady. Exterior of left valve, ×75. San Antonio Bay, No. 22A. (p. 630)

*3—Cytherura radialirata* Swain, n. sp. Exterior of a right valve, ×75. San Antonio Bay, No. 68A. (p. 626)

*4—Perissocytheridea bicelliforma* Swain, n. sp. Exterior of a probably immature left valve, ×75. San Antonio Bay, No. 16A. (p. 621)

*5—Cytheromorpha pascagoulaensis* Mincher. Exterior of a right valve, ×75. San Antonio Bay, No. 90A. (p. 630)

*6—Paracytheridea troglodyta* Swain, n. sp. Exterior of an immature right valve, ×75. San Antonio Bay, No. 16A. (p. 623)

*7—Microcythere johnsoni* Mincher. Interior of a right valve, ×75. San Antonio Bay, No. 22A. (p. 641)

*8a–c—Cytherura johnsoni* Mincher. *8a*, Exterior of right valve having longitudinal ridges prominent. *8b*, Right side of specimen showing reticulate ornamentation. *8c*, Exterior of a more elongate dimorphic? left valve, questionably referred to the species, ×75. *8a, c*, San Antonio Bay, No. 28A; *8b*, No. 6A. (p. 627)

*9—Cytherura rara* Müller. Right side of an immature? shell, ×75. San Antonio Bay, No. 16. (p. 628)

*10a–c—Cytherura forulata* Edwards. *10a*, Right side of a complete shell. *10b*, Interior of a left valve. *10c*, Exterior of an immature? left valve, questionably in the species, ×75. *10a, b*, San AntonioBay, No. 26A; *10c*, No. 6A. (p. 628)

*11a, b—Cytherura costata* Müller. Left side and right side respectively of two complete shells, × 5. San Antonio Bay, No. 10. (p. 629)

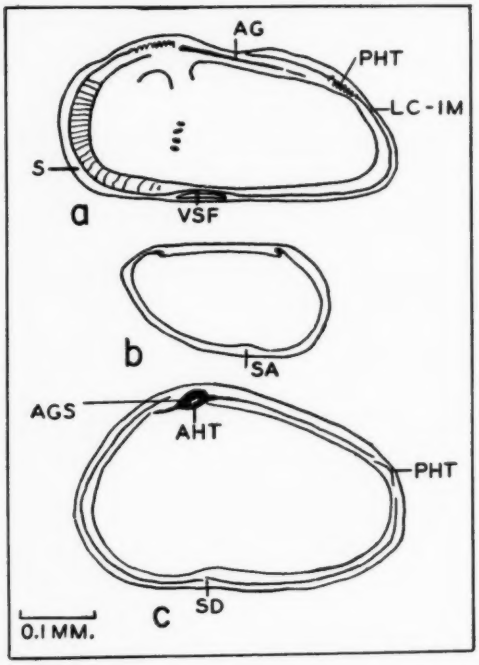
*12a, b—Cytherura elongata* Edwards. *12a*, Exterior of an immature? left valve. *12b*, Right side of a complete shell, ×75. *12a*, San Antonio Bay, No. 50; *12b*, No. 28A. (p. 628)

*13—Cyprideis locketti* (Stevenson). Right side of an immature specimen, ×75. San Antonio Bay, No. 3A. (p. 615)

*14—Hemicytherideis?* sp. Right side of a complete shell, ×75. Open Gulf, No. J31A. (p. 632)

*15—Neomonoceratina* sp. Left side of a shell which has caudal process slightly broken, ×75. Open Gulf, No. J5A. (p. 643)

*16a, b—Cythere?* sp. Exterior views of a right and a left valve, ×75. Open Gulf, No. J6A. (p. 642)




TEXT-FIG. 34—Outline drawings. a, *Paracytheridea troglodyta*, n. sp., interior of right valve, San Antonio Bay, No. 26A. b, *Monoceratina?* sp., interior of left valve, San Antonio Bay, No. 3A, c, *Cytheromorpha pascagoulaensis* Mincher, right valve interior, San Antonio Bay, No. 74A. PHT, posterior hinge tooth; AG, accommodation groove; AGS, anterior girdle socket; AHT, anterior hinge tooth; VSF, ventral selvage furrow; SA, selvage apophysis; SD, selvage discontinuity.

San Antonio Bay, No. 30A. Rare at a few stations in lower bay. Described elsewhere from the middle and upper Miocene at the Atlantic coast.

### Subfamily CYTHERURINAE Müller, 1894

Shell subquadrate; frequently with ventral alate expansions and posterior compressed caudal extensions. Hinge of right valve with terminal teeth and sockets. Marine and brackish-water; Cretaceous? to Recent; worldwide distribution.

*Remarks.*—This subfamily is of uncertain status (Sars, 1925). Its distinguishing features, such as alation, hingement, posterior caudation, etc., are also found in other subfamilies of Cytheridae. Possibly the hingement is distinct.

### Genus CYTHERURA Sars, 1866

Subquadrate; with a straight segment of hinge margin, either short or long; posterior caudation varying from greatly extended to nearly obsolescent; surface typically with longitudinal rows of pits or reticulations, or ridges. Hinge of right valve with anterior small tooth, postjacent socket, interterminal crenulate groove, posterior small socket and postjacent tooth. Inner lamellae typically broad anteriorly with irregular line of concrescence. Type species, *Cythere gibba* O. F. Müller, 1785. Marine and brackish-water; Cretaceous to Recent; worldwide distribution.

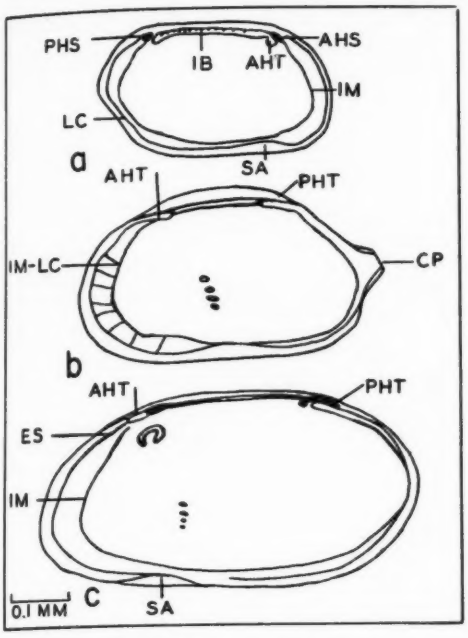
#### CYTHERURA RADIALIRATA Swain, n. sp.

Plate 63, figures 8a,b; Plate 64, figure 3; Text-figure 35a

Shell short-subquadrate; dorsal margin straight, with obtuse but distinct cardinal angles, ventral margin slightly concave medially; anterior margin broadly rounded, slightly extended below; posterior margin also broadly rounded but with short, blunt caudal process dorsad of midheight. Valves approximately equal in size, convexity of valves moderate, greatest slightly behind middle. Surface ornamented by a series of sinuous narrow ridges, radiating from middle part of valve; a subsidiary poorly developed network of lower reticulating ridges occurs in between these ridges; a narrow marginal ridge, and accompanying inner ridge occurs anteriorly; ventrally several narrow ridges occur parallel to margin.

Hinge of left valve consists of an anterior small socket, postjacent low pointed tooth, interterminal bar, bearing faint notches and surmounted dorsally by a narrow rabbet-groove; a posterior small tooth and postjacent socket. Hinge of right valve is the antithesis. Inner lamellae broad; line of concrescence and inner margin separated; postventrally, inner lamella forms a selvage for reception of edge of opposite valve; elsewhere there is a small selvage shelf bordering free margin. Muscle scar not clearly observed.

Length of holotype, an adult left valve




TEXT-FIG. *35*—Outline drawings. a, *Cytherura radialirata*, n. sp., interior of left valve, San Antonio Bay, No. 3A. b, *Cytherura johnsoni* Mincher, interior of right valve, San Antonio Bay, No. 6A. c, *Cytherura forulata* Edwards, interior of right valve, San Antonio Bay, No. 6A. PHS, AHS, posterior and anterior hinge sockets; AHT, PHT, anterior and posterior hinge teeth; IM, inner margin; LC, line of concrescence; CP, caudal process; ES, eye spot; SA, selvage apophysis.

(Pl. 64, fig. 3), 0.36 mm., height 0.31 mm., convexity of valve 0.10 mm.

*Relationships.*—The pattern of surface ornamentation and compressed valves distinguish this species. In its surface pattern of ridges it somewhat resembles *Cytherura gibba* (O. F. Müller).

*Occurrence.*—The holotype is from San Antonio Bay, No. 68A.

CYTHERURA JOHNSONI Mincher
Plate 64, figures 8a–c; Text-figures 35b and 38, 8a,b and 39, 1a–c

*Cytherura johnsoni* MINCHER, 1941, Jour. Paleontology, vol. 15, p. 343, pl. 47, figs. 1a-d.

Outline of shell lozenge-like to subreniform; highest medially; dorsum moderately convex with a short, straightened, median section; ventral margin slightly convex to sinuous; anterior margin broadly rounded, extended medially to ventromedially; posterior margin with strongly extended, blunt, dorsomedian caudal process. Left valve the larger, extending beyond the other ventrally and posteriorly. Surface with about 8 well-developed longitudinal ridges, with reticulating cross-bars in late instar and mature valves. Valves with moderate convexity which is greatest medially.

Hinge of right valve consists of an anterior small tooth, an interterminal depressed grooved area, and a posterior tooth-like ridge formed of an extension of valve margin. Hinge of left valve consists of an anterior rounded socket, a postjacent tooth, an interterminal rabbeted bar and a posterior tooth. The left valve teeth fit into notched depressions adjacent to the terminal tooth-elevations of the left valve; interterminally there is a rabbet-groove arrangement of the valve edges. Inner lamellae moderately wide, vestibule narrow, radial canals widely spaced.

Antennules each consist of five podomeres, ultimate one produced as a claw and with one seta; penultimate and third podomeres each bear a seta. Each antenna with long exopodite flagellum reaching nearly to distal end of appendage; ultimate podomere with three claws; a single ventral seta occurs on penultimate podomere. Leg bears a strong terminal forward-pointing claw. Copulatory apparatus trilobate with fan-shaped dorsal lobe which has a radiating structure.

Length of paratype (Pl. 64, fig. 8b) 0.40 mm., height 0.25 mm., convexity 0.20 mm.

*Relationships.*—This species is characterized by subreniform outline, arched dorsum, prominent, blunt, slightly dorsomedian caudal process, strong left valve overlap, and generally reticulate surface on which, however, in immature and some adult specimens the longitudinal elements greatly dominate over the transverse crossbars.

*Occurrence.*—The figured specimens are from San Antonio Bay, Nos, 6A and 28A. Very abundant in San Antonio Bay with greatest frequency more toward margins than middle of bay. The present specimens are indistinguishable from Mincher's species

from the Miocene Pascagoula formation of Louisiana.

### CYTHERURA ELONGATA Edwards
Plate 64, figures 12a–b

*Cytherura elongata* EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 526, pl. 88, figs. 21–25.

The molts of this species are very difficult to distinguish from those of *Cytherura johnsoni* Mincher. The adults are typified by the following characteristics: shell elongate-subquadrate, nearly straight, long hinge margin; median to dorsomedian blunt posterior caudal extension; moderate left valve overlap; reticulate ornamentation with the surfaces of the small depressions convex upward; posterodorsal dimorphic swelling in presumed female specimens.

Length of a figured specimen (Pl. 64, fig. 12b) 0.48 mm., height 0.24 mm., convexity 0.22 mm.

*Occurrence.*—The figured specimens are from San Antonio Bay, Nos. 22A, 28A and 50A. Rare to absent in upper part of bay; rare to common at scattered stations in lower bay and on Matagorda Island. Also in upper Miocene of Atlantic coast.

### CYTHERURA RARA Müller
Plate 64, figure 9

*Cytherura rara* MÜLLER, 1894, Fauna und Flora des Golfes von Neapal, vol. 21, p. 299, pl. 17, fig. 14, 15; pl. 19, fig. 20.
*Cytherura gracilis* LIENENKLAUS, 1895, in Jahresber. ver. Osnabrük, vol. 10, p. 149, pl. 3, figs. 3 a-c.

Shell subpyriform in lateral view; highest about one-third from anterior end; dorsal margin moderately convex; ventral margin slightly convex; anterior margin broadly and almost uniformly rounded; posterior margin pointed with median to slightly ventromedian caudate process. Left valve only slightly larger than right. Valves moderately convex, with greatest thickness ventromedian. Surface bears weak longitudinal ridges, joined by obscure crossbars to form a general reticulate pattern; anterodorsally is a small eye tubercle which has a low ridge running from it anteriorly and ventrally; a weak median depression occupies dorsal half of valve.

Hingement weak in specimens examined; possibly all of which are immature; in left valve there are weak, crenulated, terminal sockets and an interterminal rabbeted bar; in the right, weak elongate, crenulated, terminal teeth and interterminal rabbet-groove. Inner lamellae of moderate width anteriorly; very delicately calcified; vestibule present. Other internal features not clearly seen.

Length of figured specimens 0.39 mm., height 0.19 mm., convexity 0.17 mm.

*Remarks.*—The pear-shaped carapace and weak ornamentation provide a comparison of this species with *C. rara* G. W. Müller (1894) from the Gulf of Naples, but the ornamentation in Müller's specimens is perhaps stronger than on the San Antonio Bay specimens.

*Occurrence.*—The figured specimen is from San Antonio Bay, No. 16A. Rare to absent in upper part of bay; rare to common at a few stations in lower bay and on Matagorda Island. Recorded originally from the Gulf of Naples.

### CYTHERURA FORULATA Edwards
Plate 64, figures 10a–c; Text-figures 35c and 39, 2a,b

*Cytherura forulata* EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 526, pl. 88, figs. 21–25.

This species has the following characteristics: shape oblong-ovate, dorsum slightly arched, ventrum nearly straight; ends rounded, the posterior the broader and lacking a caudal extension of the margin; surface reticulate; a swelling of valve surface occurs posteriorly in some specimens, probably females.

Antennules have five podomeres, the last three dorsally setose and with slender terminal claw. Antennae bear three podomeres, the ultimate one elongate and armed with two posteriorly curved claws; exopodite flagellum extending beyond end of appendage and sharply bent near its distal end.

Length of a figured shell (Pl. 64, fig. 10a) 0.47 mm., height 0.27 mm., convexity 0.24 mm.

*Remarks.*—This species is similar to *C. elongata* Edwards but differs in its lack of posterior caudal process and more convex dorsum.

*Occurrence.*—The figured specimens are from San Antonio Bay, Nos. 6A and 26A. Rare to frequent at scattered stations on

Matagorda Island and at a very few stations in San Antonio Bay.

CYTHERURA COSTATA Müller
Plate 64, figures 11a, b

*Cytherura costata* MÜLLER, 1894, Fauna und Flora des Golfes von Neapal, vol. 21, p. 295, Pl. 8, figs. 11, 15; Pl. 32, fig. 33.

Shell sublanceolate; highest one-third from anterior end; hinge margin nearly straight and comparatively short, about half of shell length, anterior end rounded, extended below; posterior end with strongly extended, pointed caudal process lying ventrad of midheight. Valves approximately equal, the left slightly larger. Convexity moderate, greatest posteriorly. Surface ornamented with high, narrow ridges; the floors of the intervening broad grooves delicately pitted. Posterior caudal portion strongly compressed.

Internal features not clearly seen.

Length of figured shell (Pl. 64, fig. 11b) 0.36 mm., height 0.16 mm., convexity 0.13 mm.

*Remarks.*—The outline; prominent narrow surface ridges and ventral position of the strongly extended caudal process are features that ally the present specimens with *C. costata* Müller of the Gulf of Naples.

*Occurrence.*—Figured specimens from San Antonio Bay, No. 10A. Originally described from Gulf of Naples.

Subfamily LOXOCONCHINAE Sars, 1926

Shell subrhomboidal; in part without ventral alae (*Loxoconcha*) and in part with these alae (*Cytheropteron*). Surface smooth or pitted; free marginal portion with a compressed border; hinge complex, consisting in right valve of terminal teeth with modifying structures and an interterminal groove. Muscle scar cythereid. Marine and brackish-water. Cretaceous to Recent, worldwide distribution.

Genus LOXOCONCHA Sars, 1866

Shell rhomboidal, subquardrate to subovate; surface not alate; smooth or pitted; with marginal rim; hinge in right valve bears anterior small tooth, flanked dorsally and on either side by a furrow; an interterminal groove, and a posterior yoke-shaped tooth. Type species, *Cythere impressa* Baird, 1850. Marine and brackish-water; Cretaceous to Recent; worldwide distribution.

LOXOCONCHA MATAGORDENSIS
Swain, n. sp.
Plate 63, figures 9a,b; Plate 64, figures 1a,b; Text-figures 36b and 39, 7a,b

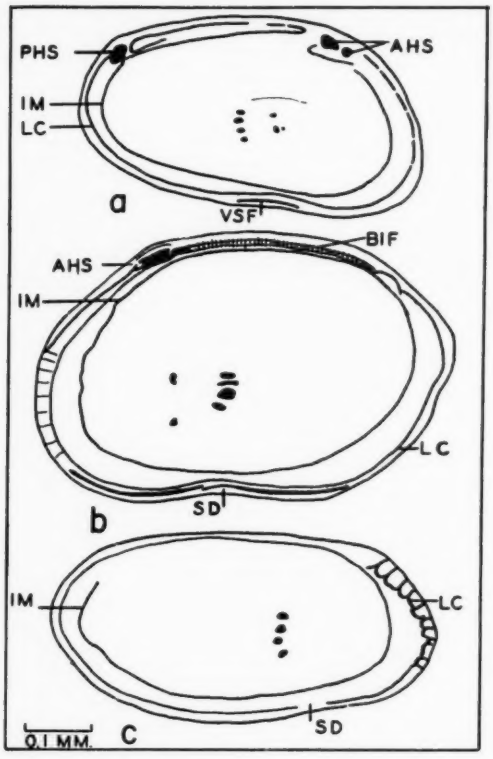
Shell subrhomboidal; highest medially to posteromedially; dorsal margin nearly straight, about three-fifths of shell length; ventral margin sinuous, concave anteromedially in most specimens; anterior margin broadly rounded, extended below, truncate above; posterior margin also broadly rounded, extended above, and with a concavity below posterodorsal cardinal angle. Left valve slightly larger than right; valves moderately convex; greatest medially. Most of shell ornamented by tiny pits; superimposed over this ornamentation is a weak reticulate network of ridges; marginally, pits disappear, but reticulate network remains. Species dimorphic, the females? being relatively larger and more elongate.

Hinge of right valve consists of an anterior small elongate socket bordered on either side by tiny rounded teeth which are yoked dorsally by a small ridge; interterminally are two very narrow parallel grooves crossed by many transverse crenulae, a structure here called the bipartite interterminal furrow; and a posterior elongated tooth. Hinge of left valve the antithesis, with the yoke-structure located posteriorly. Inner lamellae broad; line of concrescence and inner margin separated; radial canals rather sparse. Muscle scar as shown in Text-figure 36b.

Antenna consists, in the endopodite portion, of two podomeres, each of which apparently involves fusion of two podomeres; penultimate segment bears a long dorsal exopodite flagellum and two short ventral setae, ultimate podomere has one ventral seta and two stout terminal subequal claws; leg with penultimate segment formed by fusion of two or three podomeres; ultimate podomere bears a long curved claw.

Length of holotype, a male right valve, 0.55 mm., height 0.37 mm., convexity 0.14 mm.

*Relationships.*—This species is close to one described by Edwards from the Duplin




TEXT-FIG. *36*—Outline drawings. a, *Campylocythere concinnoidea*, n. sp., interior of rig-valve, San Antonio Bay, No. 10A. b, *Loxoconcha matagordensis*, n. sp., interior of right valve, San Antonio Bay, No. 193A. c, *Paradoxostoma atrum* Müller, interior of left valve, San Antonio Bay, No. 12A. AHS, PHS, anterior and posterior hinge sockets; BIF, bipartite inter terminal furrow; IM, inner margin; LC, line of concresence; SD, selvage discontinuity; VSF, ventral selvage furrow.

marl, upper Miocene of North Carolina, but differs in the development of the subsidiary reticulate network of weak surface ridges.

*Occurrence.*—The holotype is from San Antonio Bay, No. 193A. Frequent to common at scattered stations in lower bay and on Matagorda Island.

### LOXOCONCHA AUSTRALIS Brady
Plate 63, figure 11; Plate 64, figure 2

*Loxoconcha australis* BRADY, 1880, Challenger Repts., Zool., vol. 1, p. 119, pl. 28, figs. 5 a-f; pl. 29, figs. 3 a-d.

A few shells possibly belonging in this species were obtained from San Antonio Bay and the open Gulf. The shell is oblong-subquadrate with the posterior extension of the valve margin located near posterodorsal angle. The surface is rather coarsely reticulate in a concentric pattern.

Length of figured specimen 0.50 mm., height 0.32 mm., convexity of valve 0.12 mm.

*Occurrence.*—San Antonio Bay, No. 22A. Also frequent in open Gulf stations. Originally obtained off Port Jackson, Australia, and off Booby Island.

### Genus CYTHEROMORPHA Hirshmann, 1909

Shell subquadrate, subovate to subreniform; highest anteriorly; terminal margins rounded, extended below; cardinal angles more or less distinct, obtuse; valves compressed; ornamented with small pits; frequently with low alate expansion of ventral surface; smooth border. Hinge of right valve with rounded anterior tooth surrounded by a furrow; interterminal narrow groove; and posterior double or U-shaped tooth structure; marginal area of moderate width. Type species, *Cythere fuscata* Brady, 1868 (1869?). Marine and brackish-water. Paleocene to Recent; Europe, North America.

*Remarks.*—This genus is very close to *Leptocythere* and the two probably should be grouped in the same subfamily. The relationships of Jurassic species assigned to *Leptocythere* by Swain and Peterson (1949, 1951) to modern *Leptocythere* and *Cytheromorpha* is not at present clear.

### CYTHEROMORPHA PASCAGOULAENSIS Mincher
Plate 63, figure 4; Plate 64, figure 5; Text-figure 34c

*Cytheromorpha pascagoulaensis* MINCHER, 1941, Jour. Paleontology, vol. 15, p. 344, pl. 47, fig. 2.

This species is characterized by a short, relatively high shell, arched dorsum, with greatest height about one-third from anterior end; broadly rounded, dorsally truncate anterior margin; concave venter; and coarsely pitted surface. The right valve hinge bears an anterior semicircular socket in which is a small oval tooth; an interterminal narrow groove; and a posterior curved, narrow tooth. The present speci-

mens seem identical with those from the Miocene.

*Occurrence.*—The figured specimens are from San Antonio Bay, Nos. 74A and 90A. Described from upper Miocene of Mississippi. *C. curta* Edwards (1944) from the upper Miocene of North America may be the same as this species.

### Subfamily XESTOLEBERINAE Sars, 1928

Shape of shell varying from subovate-reniform to elongate-sublanceolate; muscle scar typically cythereid in consisting of a subvertical median to anteromedian row of four spots, with or without more anterior spots; with or without anterodorsal shell-scar which may be related to the lateral eyes; hinge consisting of elongate right valve bar and left valve groove in anterior half, and of right valve groove and left valve bar in posterior half, with additional posterior short tooth and socket at posterior end of hinge. Left valve typically the larger; surface smooth, pitted or pustulose; an anteromedian, dorsal, weak sulcus may occur. Species typically dimorphic. Jurassic to Recent; marine and freshwater; worldwide distribution.

*Remarks.*—Sars' subfamily is here expanded to include *Hemicytherideis* and related "cytherideisid" ostracodes; these relationships based on the similarity of the hinge structures. The essential soft part features are cythereid (Sars, 1928, p. 343).

### Genus HEMICYTHERIDEIS Ruggieri, 1952

*Cytherideis* [part] JONES, 1856, in Forbes, E., Mem. Geol. Surv. Gr. Brit., pp. 157–158, pl. 7. (Synonym of *Cypridea*, cf. Sylvester-Bradley, 1953).

*Hemicytherideis* RUGGIERI, 1952, Note del laboratorio di biol. marine di Fano, vol. 1, pp. 57–64.

Elongate subelliptical to sublanceolate shells, with left valve overlap, pitted, papillose or smooth surface; a muscle scar pattern of four spots arranged in a vertical row and one or more additional more anterior scars; width of inner lamellae moderate to broad; anteriorly there is a well defined vestibule, hinge of right valve consists in anterior half of a bar-like extension of valve edge, and in posterior half of a groove, in some instances faintly crenulate and a posterior short, tooth-like elevation. Hinge of left valve has an anterior groove, set in extended valve edge, and with dorsojacent accommodation shelf, a posterior bar, which may be faintly crenulate and a postjacent short socket. Type species, *Cytheridea elongata* Brady, 1868. Marine and brackish-water; Miocene-Recent; worldwide distribution.

*Remarks.*—A discussion of the taxonomic problems involved in this group of ostracodes is given by Sylvester-Bradley (1953, p. 755).

#### HEMICYTHERIDEIS aff. H. MAYERI (Howe and Garrett)
Plate 63, figure 3

Shell elongate-subelliptical; highest slightly anterad of midlength; dorsal margin gently convex, ventral margin slightly concave; terminal margins rounded, extended below, the posterior slightly more pointed than anterior. Surface bears a subvertical narrow sulcus, slightly in front of midlength, extending from dorsal margin about two-fifths of shell height from dorsal margin; a second short vertical groove extends a short distance downward from anterodorsal marginal bend; two small pits occur medially; one is ventral to the other. General surface ornamented with closely spaced pustules, anteriorly and ventrally, pustules are arranged in rows roughly parallel to valve margin.

Hinge of left valve consists in anterior half of a long narrow groove formed in valve edge and in posterior half of the bar-like valve edge and dorsally adjacent accommodation shelf. Hinge of right valve not seen. Inner lamellae broad anteriorly, of moderate width elsewhere; line of concrescence and inner margin widely separated anteriorly. Line of concrescence scalloped, resulting in funnel-shaped inner terminations of radial canals; these canals numerous around free margins.

Length of figured left valve 0.70 mm., height 0.29 mm., convexity of valve 0.14 mm.

*Remarks.*—The species, although rare, has distinctive and easily recognizable characteristics in the shape, pustulose surface, and oblique dorsomedian sulcus. It has not been possible to place the specimens in a described species, but the general shape and

sulcus are like *Hemicytherideis mayeri* (Howe and Garrett) (cf. Cheetham, 1952, Schmidt, 1948). That species, however, has a reticulate rather than a postulose surface.

*Occurrence.*—San Antonio Bay, No. 109A. The species occurs in the Eocene Wilcox group of the Gulf Coast.

### HEMICYTHERIDEIS sp.
Text-figure 32b

Shell elongate-subquadrate in side view; highest about three-fifths from anterior end; dorsal margin gently convex; ventral margin gently concave; ends rounded, extended below, the posterior truncate above.

Surface ornamented by large pits; the interspaces equalling or exceeding half the diameter of the pits; medially is a short vertical groove, marking position of muscle scar; slightly anterad of middle and beginning near dorsal margin is a narrow subvertical groove which extends to midheight in front of median groove; a narrow rim borders anterior and anteroventral margin.

Hinge of left valve bears an anterior long deep groove which opens onto inner lamella anteriorly; an interterminal, faintly crenulate bar formed of valve edge, and a posterior socket-like depression. Right valve hinge not seen.

Muscle scar a vertical anteromedian row of four spots, with a single more anterior spot. Inner lamella broad; line of concrescence and inner margin separated terminally; line of concrescence strongly scalloped anteriorly; radial canals numerous, arranged partly in groups of two to four.

Length of figured left valve 0.62 mm., height 0.30 mm., convexity of valve 0.17 mm.

*Remarks.*—The shape pattern of surface pitting and faint sulcus define this species. It has not yet been possible to relate it to a described species.

*Occurrence.*—San Antonio Bay, No. 32A. Rare to frequent at a few stations in lower bay and one station on Matagorda Island.

### HEMICYTHERIDEIS? sp.
Plate 64, figure 14

Shell elongate-sublanceolate; highest one-fourth from anterior end; dorsal margin nearly straight but somewhat sinuous; ventral margin slightly concave; terminal margins, rounded, extended below, truncate above, the anterior broader. Left valve larger than right. Anterodorsally there is a shallow, subvertical furrow; general surface reticulate.

Internal features not observed.

Length of figured specimen 0.39 mm., height 0.16 mm., convexity 0.11 mm.

*Remarks and occurrence.*—This species is similar to *Hemicytherideis mayeri* (Howe and Garrett) but has a more angular outline. It occurs at several of the open Gulf stations including J31 from which the figured specimen was obtained.

## Subfamily PARADOXOSTOMINAE Müller, 1894

Elongate, more or less compressed, highest medially to posteromedially; dorsum arched; venter sinuous; shell typically thin and fragile, smooth or faintly ornamented; hingement simple; inner lamellae broad; line of concrescence typically scalloped. Marine and brackish-water; Cretaceous? to Recent; worldwide distribution.

### Genus PARADOXOSTOMA Fischer, 1855

Sublanceolate to subovate, compressed; highest posteromedially; venter with slight anteromedian concavity in most species; inner lamellae of moderate width; pore canals few. Type species, by monotypy, *P. dispar* Fischer, 1855. Marine and brackish-water; Cretaceous? to Recent; worldwide distribution.

### PARADOXOSTOMA ATRUM Müller
Plate 63, figures 6a–d; Text-figures 36c and 39, 4a–c

*Paradoxostoma atrum* MÜLLER, 1894, Fauna und Flora des Golfes von Neapal, vol. 21, p. 320, pl. 23, figs. 15, 46, 50.

Shell subquadrate in side view, highest about one-third from posterior end; hinge margin nearly straight and approximately three-fifths of shell length; ventral margin sinuous with a slight concavity in anterior half; terminal margins rounded, the posterior extended medially and slightly more pointed than anterior which has its greatest extension slightly below midheight. Right valve slightly larger than left, extending

beyond the other most noticeably along dorsum. Surface smooth.

Hinge line simple, without markings other than a faint incision just within each valve margin, perhaps representing position of diductor muscle pad. Inner lamellae broad, line of concrescence and inner margin widely separated, except near cardinal angles. Line of concrescence scalloped owing to funnel-shaped terminations of rather widely spaced radial canals.

Muscle scar consists of a slightly anteromedian vertical row of small closely spaced spots of which the second from the bottom is the largest; no additional spots could be definitely seen.

Antennules with two large proximal podomeres and two smaller distal podomeres; penultimate podomere with a single dorsal seta; ultimate podomere with two dorsal and two terminal setae. Antennae consist of four podomeres, the proximal one large and sinuate; exopodite flagellum extending beyond ultimate podomere; penultimate podomere with two ventral setae; ultimate podomere with a long and a short terminal claw. First leg consists of an initial broad podomere and three long slender podomeres, the ultimate one with a single straight claw.

Length of a complete shell 0.47 mm., height 0.26 mm., convexity 0.20 mm.

*Remarks.*—The subquadrate shape of this species furnishes a comparison with Müller's specimens from the Gulf of Naples. The antennules, however, are shorter and stouter than in typical *Paradoxostoma*. A similar form has been referred to *Microcythere* (Mincher, 1941), but this assignment is questionable because of the weak hinge. A new genus may be represented by the present species.

*Occurrence.*—The figured specimens are from San Antonio Bay, Nos. 6A, 12A, and 16; common to abundant throughout most of San Antonio Bay. Originally described from the Gulf of Naples.

### PARADOXOSTOMA ENSIFORME Brady
Plate 63, figure 7

*Paradoxostoma ensiforme* BRADY, 1868, Rec. Brit. Ostr., p. 460, pl. 35, figs. 8–11. BRADY, CROSSKEY and ROBERTSON, 1874, Post-Tert. Entom., p. 215, pl. 10, figs. 27, 28. BRADY, 1880, Challenger Rept. Zool., vol. 1, p. 150, pl. 35, figs. 3a-d. SARS, 1928, Crust. of Norway, p. 258, pl. 67, fig. 1.

Shell sublanceolate in side view; greatest height slightly behind middle of shell; dorsal margin moderately convex; ventral margin sinuous with small concavity near anterior end; anterior margin rounded, slightly extended below; posterior margin bluntly pointed, with median caudate extension, dorsal to which margin is concave. Valves compressed, most convex medially. Valves subequal. Surface polished, ornamented with tiny shallow pits.

Hingement very simple, with dorsal edges of valves slightly rabbeted. Inner lamellae very broad, line of concrescence and inner margin separated. Radial canals few and widely spaced, in part branching anteriorly in a specimen questionably in the species. Muscle scar a small anteromedian vertical row of tiny spots and two widely spaced more anterior spots the dorsal one being v-shaped and the ventral one elongate.

Length of figured specimen 0.51 mm., height 0.26 mm., convexity 0.19 mm.

*Remarks.*—The present specimens are similar to *P. ensiforme* Brady, in general shape and character of the inner lamellae, but as that species is quite variable as it is figured by Brady (1880, pl. 35, fig. 3) and by Sars (1928, pl. 67, fig. 1) the present assignment is tentative. There is also considerable variation in shape, particularly in the height of the posterior caudation, in the present specimens.

*Occurrence.*—The figured specimen is from San Antonio Bay, No. 37A. Rare at a few scattered stations in southeastern bay. The species has been recorded at several localities in Europe.

### Family TRACHYLEBERIDAE Sylvester-Bradley, 1948
### Subfamily TRACHYLEBERINAE Sylvester-Bradley, 1948

"Ornate Trachyleberidae with compressed subrectangular shell, pronounced muscle scar node (='subcentral tubercle'); forms a 'muscle scar pit' when viewed from the interior; eye tubercle, posterior and anterior cardinal angles, and posterior and anterior marginal rims. Accommodation groove absent, or present only as a very narrow shelf. No vestibule. Median element

of hinge subdivided, smooth or finely denticulate" (1948, p. 793). Marine or brackish-water; Jurassic to Recent, worldwide distribution.

Genus ACTINOCYTHEREIS Puri, 1953

The genus was described by Puri to include *Cythereis*-like Ostracoda having the surface ornamented by three longitudinal rows of spines; dorsal medial and ventral in position. Hinge of right valve with anterior rounded tooth and postjacent socket, interterminal shallow groove and posterior tooth. Type species, *Cythere exanthemata* Ulrich and Bassler, 1904. Marine and brackish? water; Eocene to Recent?; worldwide distribution.

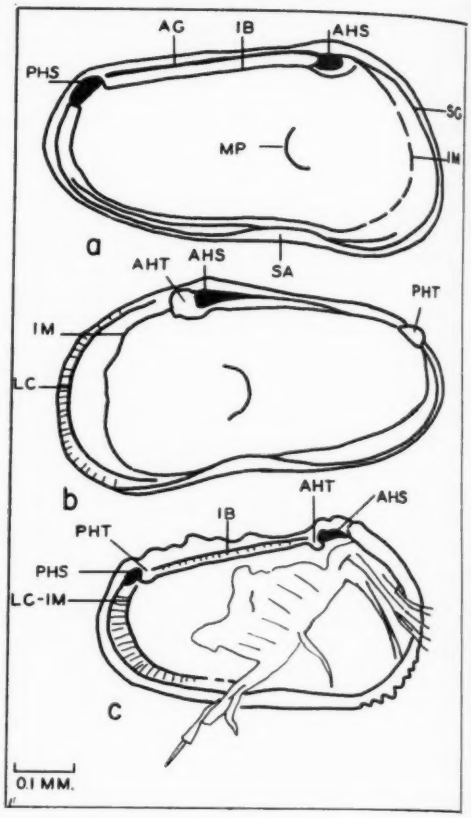
*Remarks.*—Puri restricted the range of his genus to Eocene to Miocene, but there are living representatives of this kind of ostracode, e.g., "*Cythere*" *clavigera* Brady (1880, p. 108) from Australia. It is not clear whether the features of surface ornamentation used in the establishment of *Actinocythereis* are of generic value. For the most part of the cythereid ostracode genera are based upon hinge structures or significant variations in shape, convexity, and alation of the shell.

ACTINOCYTHEREIS aff. A. EXANTHEMATA
(Ulrich and Bassler)
Plate 63, figures 5a,b; Text-figures 37c and 38, 7a–c

The specimens from the Rockport area are similar to *Actinocytheresis exanthemata* in general shape, hingement, and in surface longitudinal rows of spines, but the posterior marginal spines are much reduced, compared to typical *A. exanthemata* and all spines perhaps are shorter and thicker. Clear-cut separation from Ulrich and Bassler's species does not seem possible, however, on the basis of present evidence.

Antennules each consist of three podomeres, the penultimate with three long stout dorsal setae and a long terminal claw. Legs bear long terminal curved claws.

*Occurrence.*—The figured specimens are from San Antonio Bay, Nos. 6A and 41A. Rare to frequent at a few stations in lower bay, particularly on eastern side. Described from the middle and upper Miocene of the Atlantic coast.




TEXT-FIG. 37—Outline drawings. a, b, *Paracytheretta multicarinata*, n. sp., interior of left and right valves, San Antonio Bay, No. 40A. c, *Actinocythereis* aff. *A. exanthemata* (Ulrich and Bassler), interior of left valve which contains remnant of animal, San Antonio Bay, No. 11A. AHS, PHS, anterior and posterior hinge AHT, PHT, anterior and posterior hinge teeth; IB, interterminal bar; AG, accommodation groove; MP, median pit; IM, inner margin; LC, line of concrescence; SA, selvage apophysis.

Genus PURIANA Coryell, 1953
(FAVELLA Coryell and Fields, 1937
[not Jorgensen, 1925])

This genus is at present of uncertain status because of its close similarity to *Trachyleberis*, *Actinocythereis*, *Cythereis* and other similar genera. A complete description is given by Edwards (1944, p. 523). Type species, *Favella puella* Coryell and Fields. Marine, Miocene to Recent; worldwide distribution.

PURIANA sp.
Plate 63, figure 10

Shell subquadrate in side view; hinge margin nearly straight and about five-eighths of shell length; ventral margin slightly sinuous and subparallel to dorsum; anterior margin broadly rounded, extended below, subtruncate above, bearing four or five short spines in ventral half; posterior margin more narrowly rounded, extended medially and bearing three or four thick spines mediaally. Valves subequal, convexity moderate, highest anteromedially. Surface bears a large rounded anteromedian swelling bounded posteriorly by a shallow furrow; anterior margin bordered by a narrow ridge; anterodorsally is a small glassy eye tubercle; posterior fifth of shell strongly compressed; posterior half bears prominent nodes or low blunt spines.

Hinge of right valve consists of an anterior high pointed tooth, postjacent deep rounded socket which passes into a long interterminal weak groove, and a posterior small pointed tooth. Inner lamellae of moderate width anteriorly, narrower elsewhere; line of concrescence and inner margin slightly separated; radial canals fairly numerous having funnel-like inner terminations anteriorly; muscle scar a vertical row of three or four spots located on internal reflection of median external furrow.

Length of figured specimen, a right valve, including spines, 0.51 mm., height 0.27, mm.

*Remarks and occurrence.*—The shape hingement and surface ornamentation relate this species to *Puriana*. Insufficient specimens are at hand to allow a complete diagnosis of this shell. The species is represented at three stations on the open Gulf.

Subfamily HEMICYTHERINAE Puri, 1953

This subfamily was defined and diagnosed by Puri about as follows:

Carapace of firm consistency, calcareous, usually somewhat almond-shaped, smooth, pitted, reticulate or with longitudinal and dorsal ridges; valves unequal. Hinge of right valve with knoblike anterior tooth, postjacent socket which is continued as a groove to an outwardly directed tooth at the posterior cardinal angle. Pore canals numerous, long, closely spaced. Muscle scar pattern consists of a vertical row of four with additional three or four scars in an oblique row situated anteriorly. Marine and brackish-waters. Eocene to Recent; worldwide distribution.

Genus HEMICYTHERE Sars, 1925

Subtrapezoidal to subpyriform; broadly rounded and highest anteriorly; bluntly caudate posteriorly with posterodorsal small concavity or "notch" in margin; left valve large; surface with pits or reticulations, weak ventral alation; marginal rim; hinge of right valve with anterior strong rounded tooth and socket, interterminal groove and posterior smaller tooth. Inner lamellae broad; radial canals numerous. Type species, *Cythere villosa* Sars, 1866. Marine and brackish-water. Eocene to Recent; worldwide distribution.

HEMICYTHERE CONRADI Howe and McGuirt
Plate 62, fig. 3a–c

*Hemicythere conradi* HOWE and MCGUIRT, 1935, Florida Dept. Conserv., Geol. Bull. 13, p. 27, pl. 3, figs. 31–34; pl. 4, fig. 17. EDWARDS, 1944, Jour. Paleontology, vol. 18, p. 518, pl. 86, figs. 17, 18. SWAIN, 1951, U. S. Geol. Surv. Prof. Paper 234-A., p. 42, pl. 6, figs. 9–12. PURI, 1953, Jour. Wash. Acad. Sci., vol. 43, no. 6, p. 176, pl. 2, figs. 1, 2.

The present specimens are so closely similar to the common Miocene species from the Atlantic coastal region that there seems little reason to separate them.

*Occurrence.*—The figured specimens are from San Antonio Bay, No. 22. Common to abundant in southeastern portion of bay and in some of the stations on Matagorda Island; rare to common at a few stations along east side of upper bay. Recorded previously from the Miocene of the Atlantic coast.

CYPRIDAE OF UNCERTAIN SUBFAMILY RELATIONSHIPS

Genus PARACYTHERETTA Triebel, 1941

This genus was characterized by Puri (1952, p. 209) after Triebel (1941) as follows:

Carapace elongate ovate. Left valve larger than right, overlaps right valve all

along ventral margin and at both cardinal angles, especially the anterior. At posterior end there is a cylindically rounded, laterally compressed process. (The sense of Triebel's original statement is that the posterior end typically has a small, rounded, compressed extension of the margin.) The surface ornamented with three strong longitudinal ribs, a reticulate network and as a rule a distinct marginal rim. Hinge similar to *Cytheretta*. Type species, *Paracytheretta reticosa* Triebel. Marine and brackish? water; Cretaceous to Recent, Europe, North America.

PARACYTHERETTA MULTICARINATA
Swain n. sp.
Plate 62, figure 4; Text-figures 37a,b

Shell subquadrate in lateral view; highest about one-fourth from anterior end; dorsal margin sinuous, about two-thirds of shell length; ventral margin slightly convex, sinuous anteromedially; anterior margin broadly rounded, slightly extended below; posterior margin more narrowly rounded, slightly truncate above. Valves moderately convex, greatest convexity postmedian. Left valve larger than right.

Anterior portion of valve bears a narrow, low, rounded marginal ridge parallel to which is a second ridge about one-eighth from anterior end; broad eye tubercle lies near dorsal edge of second ridge; between the two ridges is a third low, discontinuous ridge; ventrally a narrow longitudinal ridge occupies middle two-thirds of ventral surface and terminates posteriorly in a blunt elevation; midportion of valve bears sinuous ridges, mostly longitudinal but curved in the posterior region, and with the intervening valve surface coarsely and deeply reticulate or pitted; venter and compressed posterior end also pitted. Medially, there is a small rounded tubercle posterad of which the valve surface is depressed and weakly ornamented.

Hinge of left valve consists of a deep anterior socket which is bounded ventrally by an ocular ridge and subjacent ocular socket; anterior to the socket is a high rounded tooth, a long interterminal high ridge, which narrows posteriorly, and a posterior deep socket. Hinge of right valve consists of anterior high rounded tooth, postjacent deep socket, interterminal groove which becomes a rabbet-groove posteriorly, and a posterior high pointed tooth. Inner lamellae broad with line of concrescence and inner margin not greatly separated. Radial canals numbering about 20 anteriorly, only 3 or 4 posteriorly. Normal canals large and widely spaced. Muscle scar not clearly observed.

Length of holotype, a left valve 0.55 mm., height 0.32 mm., convexity 0.17 mm.

*Occurrence.*—Holotype, San Antonio Bay, No. 35A. Rare to frequent in a few samples from lower bay and Matagorda Island marshes; rare at one station in upper bay.

*Relationships.*—The pattern of surface ornamentation is similar to that of *P. reticosa* Triebel, the type species, but has more prominent longitudinal ridges and a lower marginal rim.

Genus CAMPYLOCYTHERE Edwards, 1944

*Acuticythereis* EDWARDS, 1944, Malkin, 1953, Jour. Paleontology, vol. 27, p. 784.

Elongate-ovate to subpyriform; highest anteriorly; anterior margin rounded, extended medially or ventromedially, truncate above; posterior margin narrowly rounded to pointed; dorsal and ventral margins gently convex to sinuous, converging toward posterior, left valve slightly the larger. Surface smooth, punctate or pitted. Hinge of right valve with anterior pyramidal tooth, postjacent elongate socket opening into interterminal partly crenulate groove and posterior small elongate tooth. Inner lamellae moderately broad anteriorly; radial canals in part grouped in pairs or triplets having common point of origin along line of concrescence and diverging toward outer margin. Type species, *Campylocythere laeva* Edwards; Miocene to Recent; North America.

CAMPYLOCYTHERE CONCINNOIDEA
Swain, n. sp.
Plate 62, figures 5a–d; Text-figures 36a and 39, 8a,b

Shell subquadrate in side view; highest about one-third from anterior end; hinge margin nearly straight to slightly convex, about two-thirds of shell length; ventral margin slightly convex, sinuous medially; anterior margin broadly rounded, extended

below; posterior margin narrower, extended medially, slightly truncate above. Left valve larger than right, extending most noticeably beyond the other ventrally and at cardinal angles. Valves moderately convex with greatest tumidity in posterior half of shell. Dimorphism in the species results in the male shells being higher and more subquadrate than the females.

Free margins of each valve have a marginal zone characterized by two or three obscure low, longitudinal ridges. General surfaces ornamented with rather large closely spaced pits with the interspaces forming in the ventral half a reticulating network; in the dorsal half the network is less well defined. Slightly anterior to midlength in well preserved specimens is a small node.

Hinge of left valve consists of an anterior slightly elongate socket, a postjacent small tooth, an interterminal strong bar which broadens posteriorly, and a posterior rounded socket. Hinge of right valve correspondingly comprises terminal teeth and an intervening rabbeted valve edge, strongly depressed below the level of the teeth. In immature specimens the teeth are elongate and show traces of taxodont crenulations. Inner lamellae of moderate width, broadest anteriorly, with line of concrescence and inner margin distinctly separated. Muscle scar consists of a vertical row of four spots located on steep rear slope of anteromedian depression of inner surface; two additional spots lie on gentle front slope of depression. Radial canals numbering 15 or more and closely spaced anteriorly, fewer ventrally and posteriorly.

Antennule with endopodite portion consisting of three podomeres, of which first probably represents the fusion of two; penultimate podomere bears three short dorsal setae; ultimate podomere with a long dorsal seta and a terminal seta. Leg with distal protopodite segment bearing a short dorsal seta; endopodite portion of four podomeres, the penultimate one having a short dorsal seta.

Length of holotype 0.51 mm., height 0.27 mm., convexity 0.25 mm.

*Relationships.*—This species is similar to *Campylocythere multipunctata* (Edwards), 1944, from the upper Miocene Duplin marl of North Carolina, but that species apparently lacks the anteromedian swelling and regular ventral arrangement of the surface pits that characterize the present specimens.

*Occurrence.*—The holotype is from San Antonio Bay, No. 35A. Rare to abundant in lower bay especially in southeastern part; rare to frequent in upper part of bay and and Matagorda Island marshes.

### Genus MONOCERATINA Roth, 1928

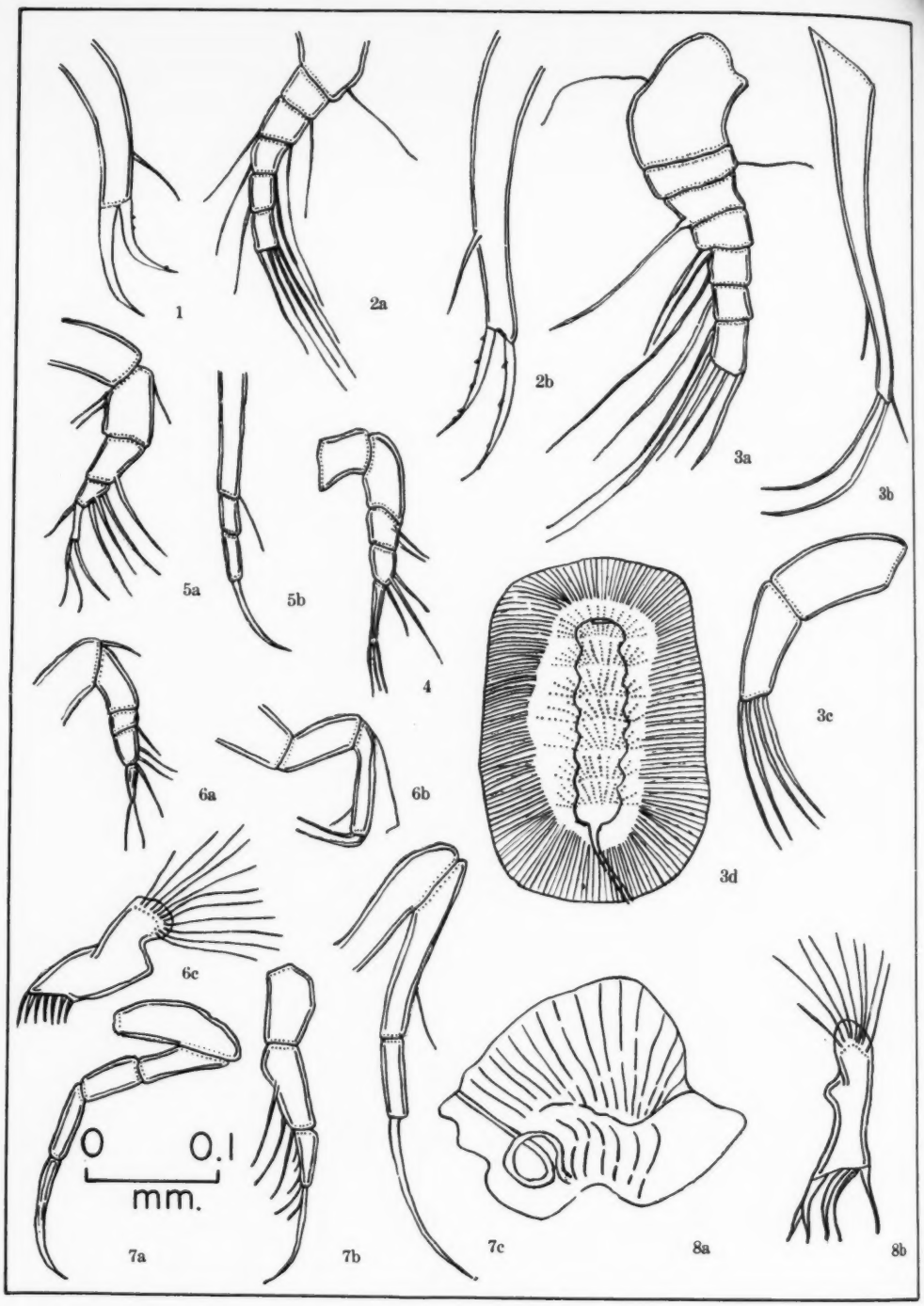
Elongate, subquadrate; dorsal margin long and straight; anterior end rounded; posterior end caudate, extended above; posteroventral surface with laterally or posteriorly projecting spines, alae or swellings. Hinge consists of a simple ridge and groove arrangement, but perhaps developing terminal elongated, shallow socket and tooth differentiations in Cenozoic. Type species, *Monoceratina ventrale* Roth, 1928. Ranges from Devonian to Recent? northern hemisphere. See Stephenson (1946, p. 312) for other remarks on the genus.

### MONOCERATINA? sp.

Plate 61, figures 6a, b; Text-figure 34b

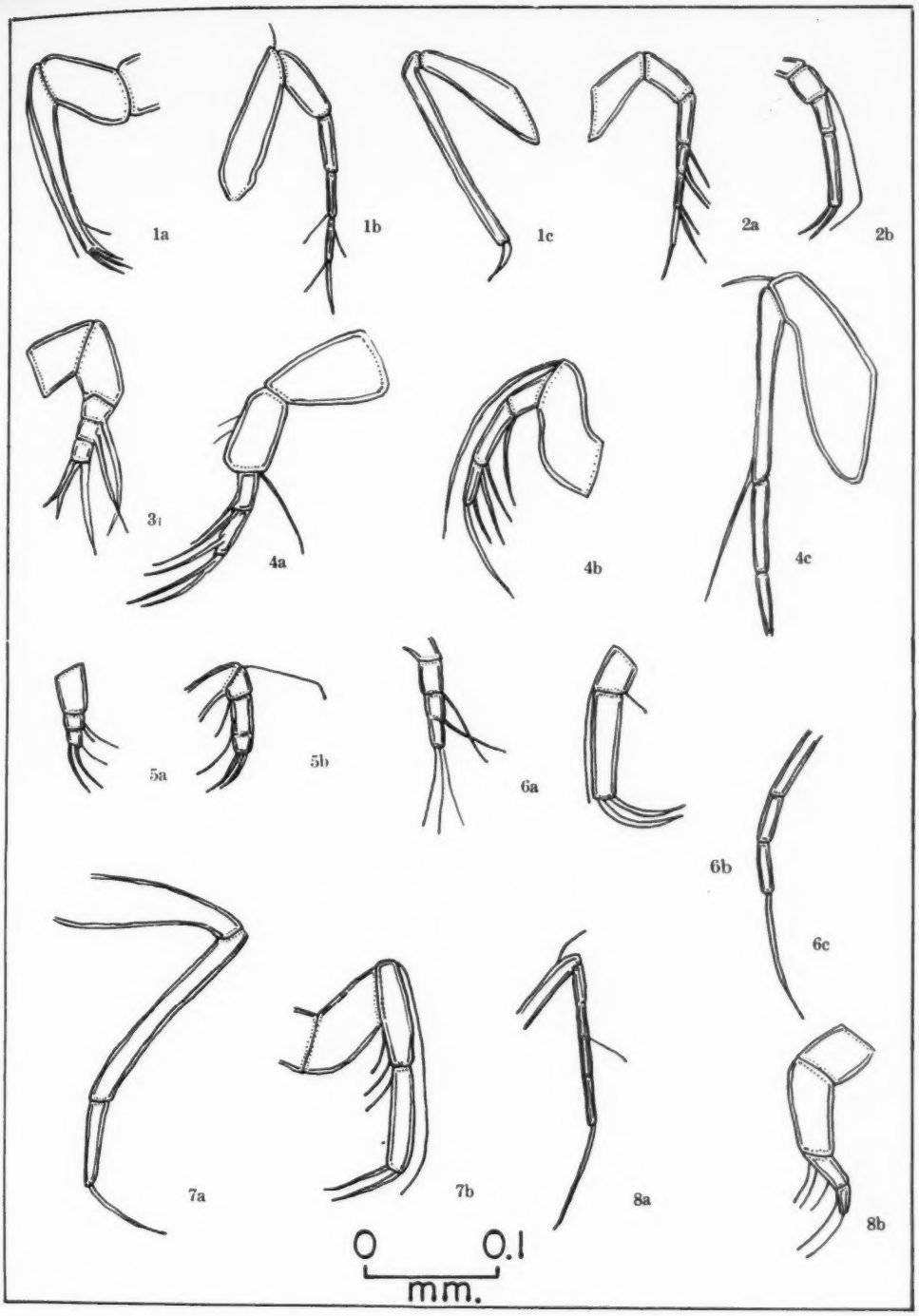
Shell subquadrate-subpyriform in side view; highest approximately one-fourth distance from anterior end; dorsal margin straight, about three-fourths of shell length and with broadly obtuse cardinal angles; ventral margin gently convex, converging strongly toward posterior with respect to dorsum; anterior margin broadly and uniformly rounded, slightly truncate near cardinal angle; posterior margin narrowly rounded, subcaudate, strongly extended just below cardinal angle. Size of valves and overlap relationships not observed. Valves moderately convex, with greatest convexity posteromedian.

Surface of each valve rather coarsely reticulated in a somewhat irregular pattern. Near anterodorsal cardinal angle is a small, slightly elevated, lucid eye tubercle. Anterior end provided with two or three narrow, weak concentric ridges that form a marginal zone; posteriorly there are one or two similar weak marginal ridges. Anteroventrally, one or more of the reticulating ridges that lies parallel to margin are slightly more elevated than their neighbors, presenting a weakly




TEXT-FIG. *38*

*1* —*Candona lactea* Baird, furca. San Antonio Bay, No. 332.
*2a, b*—*Candona obtusa* Bronstein. *2a*, Antennule; *2b*, furca; San Antonio Bay, No. 332.
*3a–d*—*Candona marchica* Hartwig. *3a*, Antennule; *3b*, furca; *3c*, antenna; *3d*, ejaculatory tube; San Antonio Bay, No. 332.
*4* —*Limnocythere sanctipatricii* Brady and Robertson, antennule; San Antonio Bay, No. 136A.
*5a, b*—*Cyprideis littoralis* Brady. *5a*, Antennule; *5b*, third leg; San Antonio Bay, No. 264.
*6a–c*—*Paracytheridea troglodyta* Swain, n. sp. *6a*, Palp of mandible; *6b*, antenna; *6c*, maxilliped with respiratory plate; San Antonio Bay No. 3.
*7a–c*—*Actinocythereis* aff. *A. exanthemata* (Ulrich and Bassler). *7a*, Second? leg; *7b*, antennule; *7c*, leg; San Antonio Bay, No. 41A.
*8a, b*—*Cytherura johnsoni* Mincher. *8a*, Copulatory apparatus; *8b*, mandible; San Antonio Bay, No. 369.




TEXT-FIG. *39*

*1a–c*—*Cytherura johnsoni* Mincher. *1a*, Antenna; *1b*, antennule; *1c*, leg; San Antonio Bay, No. 369.
*2a, b*—*Cytherura forulata* Edwards. *2a*, Antennule; *2b*, antenna; San Antonio Bay, No. 369.
*3* —*Microcythere johnsoni* Mincher. Antennule; San Antonio Bay, No. 19.
*4a–c*—*Paradoxostoma atrum* Müller. *4a*, Antennule; *4b*, antenna; *4c*, first leg; San Antonio Bay, No. 274.
*5a, b*—*Leptocythere paracastenea* Swain, n. sp. *5a*, Antennule; *5b*, antenna; Mesquite Bay, No. 11A.
*6a–c*—*Perissocytheridea brachyforma* Swain, n. sp. *6a*, Antennule; *6b*, antenna; *6c*, part of a leg; Mesquite Bay, No. 42A.
*7a, b*—*Loxoconcha matagordensis* Swain, n. sp. *7a*, a Leg; *7b*, antenna; Mesquite Bay, No. 29A.
*8a, b*—*Campylocythere concinnoidea* Swain, n. sp. *8a*, a Leg; *8b*, antennule; Mesquite Bay, No. 9A.

alate appearance to the shell. Posterior end slightly compressed.

Hinge of left valve consists of a terminal, slightly elongate, faintly crenulate weak socket; an interterminal bar formed of valve edge; and a posterior weak notch formed at intersection of hinge bar and free margin. Muscle scar not clearly seen but apparently consists of a slightly anteromedian vertical row of three or four spots. Inner lamellae very narrow, line of concrescence and inner margin almost coincide. Radial canals not observed.

Length of a figured left valve, (Pl. 61, fig. 6a) 0.25 mm., height 0.14 mm., convexity 0.05 mm.

*Relationships.*—The general outline, straight hinge margin, slight posteroventral alation, and especially a very weak hingement, furnish a relationship of this species to *Monoceratina* Roth.

*Occurrence.*—San Antonio Bay, No. 3A. The form is present at a few scattered stations in lower bay.

### Genus LEPTOCYTHERE Sars, 1925

Shell narrow, elongated, greatest height in anterior third; dorsal margin nearly straight; ventral margin sinuous; anterior margin broadly rounded, subtruncate above; posterior margin more narrowly rounded; posterodorsal angle pronounced; surface more or less faintly ornamented with pits, sometimes reticulate. Hinge of right valve consists of an anterior tooth and socket, a posterior tooth and an interterminal crenulate groove; inner lamellae moderately broad, especially anteriorly. Type species, *Cythere pellucida* Baird; marine and brackish-water; Jurassic to Recent; Europe, North America.

### LEPTOCYTHERE PARACASTANEA Swain, n. sp.
Plate 62, figure 7; Plate 63, figures 1a–c; Text-figures 39, 5a,b

Shell elongate-subquadrate to sublanceolate, immature molts and presumably male shells are less quadrate than females. Greatest height about one-fourth from anterior end. Hinge margin nearly straight, five-eighths or two-thirds of shell length, with broadly obtuse cardinal angles. Ventral margin somewhat sinuous, slightly concave medially, converging slightly with dorsum in a posterior direction. Anterior margin broadly rounded, extended below; posterior margin more narrowly rounded, extended medially, truncate above. Left valve slightly larger than right, overlapping it along dorsum. Valves moderately convex, with greatest thickness in posterior half.

Surface of valves with variable ornamentation; some specimens have coarse reticulations with the ridge-network formed of minutely beaded ridges; other specimens have this network mostly in the posterior half; still other specimens lack all except traces of the network; most specimens have the general surface minutely pitted. Anteromedially valve surface bears a narrow subvertical sulcus which terminates ventrally in two pits, the more anterior of which is also slightly more dorsally located than the other. Near anterodorsal cardinal angle is a short oblique sulcus which bounds a weak, more dorsal, eye tubercle; anterior margin with a smooth, compressed, narrow rim.

Hinge of right valve consists of an anterior tooth which occurs on a small dental platform projecting from anterodorsal inner surface; a narrow groove bounds the tooth dorsally and forms the posterior termination of a long interterminal narrow groove formed in the thickened valve edge; a posterior small, elongate, notched tooth and postjacent small socket; posteriorad of socket is a final small notched tooth. Hinge of left valve is made up of an anterior small tooth, postjacent socket, long interterminal bar formed of valve edge and posterior notched tooth defined in front, back, and dorsally by a groove.

Inner lamellae moderately wide; line of concrescence somewhat sinuous and separate from inner margin. Radial canals few and widely spaced. Muscle scar consists of a subvertical compact row of four small spots located at position of the more ventral of the two median surface pits, and an additional more anterior spot, located at position of other median pit.

Length of holotype, a male left valve (Pl. 63, fig. 1b) 0.56 mm., height 0.26 mm., convexity 0.12 mm. Length of a female paratype (Pl. 62, fig. 7) 0.49 mm., height 0.27 mm., convexity 0.20 mm.

Antennule with short terminal and penultimate podomeres; penultimate with two

dorsal setae; ultimate podomere with a short dorsal and two long terminal setae. Antenna consisting of four podomeres; the second and the ultimate ones are short; exopodite flagellum extends approximately to end of ultimate podomere; second and third podomeres each with a short ventral seta; ultimate podomere with two long terminal setae, the ventral one the longer.

*Remarks.*—This species is so variable in surface ornamentation that identification of it with described species of *Leptocythere* is difficult on the basis of material available to the writer. In shape it is close to *L. castanea* Sars, a living littoral form along North Atlantic coasts. The beaded surface reticulated ridges in combination with the finely pitted surface are different from *L. castanea*.

The hinge of this species is one of the most complex Cytheridae hinge structures that has been seen by the writer.

*Occurrence.*—Figured specimens, San Antonio Bay, Nos. 6A, 16, 90A. Rare to common throughout bay, rare in Matagorda Island marshes.

### Genus MICROCYTHERE Müller, 1894

The following diagnosis of the shell of members of genus was given by Stephenson (1935, p. 190) adapted from Müller (1894, p. 327).

Carapace thin, fragile, smooth, gradually flattened on the ventral margin; inner margin extending in a broken line or more or less S-shaped line about half the distance between the muscle scars and the anterior end. Line of concrescence slightly inside the outer margin of the carapace and parallel to it on the anterior and posterior ends, coinciding with the inner margin along most of the ventral side. Marginal pore canals present in moderate number, mostly unbranched; radial pore canals distinct. Marginal zone narrow but entire, usually not extending above the outer margin of the carapace. The muscle scars are five in number, consisting of a vertical row of four scars, anterior to which a fifth is added.

Undue emphasis perhaps is placed by Müller on marginal features in the above description, although these are, of course, important. The present writer is impressed by the subquadrate shape, well defined cardinal angles, in combination with the tear-drop shaped anterior hinge tooth in right valve and the terminal hinge teeth in left valve. This type of hingement appears unique among ostracodes. Type species, *Microcythere inflexa* Müller, Van den Bold (1946, p. 26); marine and brackish-water; Miocene to Recent; Europe, North America.

Representatives of this genus have been collected by W. T. Rothwell from the Gulf of Mexico and from salt marshes in southern California.

### MICROCYTHERE JOHNSONI Mincher

Plate 63, figures 2a–c; Plate 64, figure 7; Text-figure 39, 3

*Microcythere johnsoni* MINCHER, 1941, Jour. Paleontology, vol. 15, p. 344, pl. 47, figs. 4a-d.

Shell subquadrate, dimorphic; male? shells lower, relatively more elongate than females? and with subparallel dorsal and ventral margins; females with greatest height about two-sevenths from posterior end. Hinge margin nearly straight to slightly concave, three-fifths to two-thirds of shell length and with broadly obtuse cardinal angles; ventral margin slightly concave; anterior margin broadly rounded, extended medially; posterior margin in male? rounded about equally with anterior; in female? it appears more broadly rounded than anterior because of heightening of posterodorsal cardinal area, actually it is about equally rounded with anterior margin; is extended below and truncate above. Left valve larger than right, extending beyond the other posteriorly. Valves compressed, greatest convexity in posterior half.

Surface ornamented by longitudinal, in part discontinuous and branching ridges, except for a narrow marginal zone which is smooth. Dorsal half of each valve bears a shallow median depression.

Hinge of right valve consists of an anterior tear-drop shaped tooth which projects from anterodorsal interior surface and a posterior small articulating socket. A small socket depression is defined by rear portion of the anterior tooth. Hinge of left valve consists of anterior prominent tooth, near contact line of valve, fitting into weak socket associated with tooth of right valve; posteriorly there is a weak tooth and postjacent oblique groove.

Inner lamellae relatively broad, sloping gently at anterior end, more steeply elsewhere; line of concrescence and inner margin separated anteriorly. Radial canals rather widely spaced, present around entire margin, occurring in pairs, about 10 pairs occur anteriorly. Muscle scar obscure; as seen by transmitted light in one specimen it consists of a slightly anteromedian curved, subvertical row of four spots, perhaps with one or two additional, more anterior, spots. Slightly anterad of midlength, in right valve, where ventral margin is slightly incurved, a short flange formed from ventral shell surface forms a chord to this incurvature; the resulting short slot is for reception of a corresponding projection on left valve.

Antennules bear a long stout dorsal seta on each of the second and third podomeres, and three terminal long setae on the ultimate podomere.

Length of a figured specimen (Pl. 63, fig. 2b) 0.44 mm., height 0.24 mm., convexity 0.17 mm.

*Relationships.*—The shape, hingement musculature and character of the antennules of this species furnish a relationship to *Microcythere* Müller and the surface ornamentation is like that figured for *M. johnsoni* Mincher. The right valve anterior hinge tooth is unusual in being constructed from the inside valve surface rather than being developed as a structure from the valve edge, the typical condition. The anteromidventral slot in the right valve is also a unique structure.

The species is similar if not identical to those obtained by W. T. Rothwell from the Gulf of Mexico and from bays in southern California.

*Microcythere johnsoni* Mincher (1941) from the Miocene Pascagoula formation of Louisiana is so closely similar to the present forms in shape and surface ornamentation that it is not now possible to separate them.

*Occurrence.*—Rare to common in lower bay; rare in upper bay and Matagorda Island marshes.

### Genus CYTHERE O. F. Müller, 1785

Van den Bold (1946, p. 23) provided the following diagnosis: Carapace ovate, no strong ornamentation. Hinge taxodont; in the left valve two denticulate sockets with a carved ridge in between. Marginal area crossed by irregular porecanals, line of concrescence and inner margin not coinciding. Left valve slightly longer than the right. Some sexual dimorphism occurs. Type species, *C. lutea* O. F. Müller. Miocene to Recent, worldwide distribution.

### CYTHERE? sp.
Plate 64, figures 16a,b

Shell subpyriform in side view; highest about one-fourth from anterior end; high margin nearly straight, about three-fifths of shell length; ventral margin gently convex; anterior margin broadly rounded, extended below; posterior margin narrower, extended above. Left valve larger than right, overlapping it; valves moderately convex, greatest convexity posteromedian.

Surface of each valve bears a median longitudinal ridge, a ventromedian longitudinal ridge and a third ridgelike elevation along midportion of dorsum; general surface rather coarsely but weakly reticulate, with terminal portions nearly smooth in some specimens.

Hinge of right valve consists of an anterior elongate, faintly notched pointed tooth, an interterminal narrow weakly crenulate groove and a small posterior elongate pointed tooth; hinge of left valve corresponding comprises terminal elongate sockets and an interterminal crenulate bar. All hinge structures are remarkably weak for size of shell. Inner lamellae very narrow. Muscle scar not observed.

Length of a figured left valve 0.63 mm., height 0.37 mm., convexity 0.16 mm.

*Remarks.*—The generic status of the species is uncertain, because of the weak hingement and narrow inner lamellae. All the specimens at hand may be immature molts. If adult the hingement is close to that of *Cythere*, although externally the species resembles some *Paracytheretta* Triebel or *Leniocythere* Howe.

*Occurrence.*—The figured specimens are from the open Gulf, Station J5A. Frequent in most of the other Gulf stations.

### Genus NEOMONOCERATINA Kingma, 1948

The following description of the genus was given by Kingma (1948, p. 94):

Medium-sized, heterodont, subequal

valved Ostracoda. The valve ornamentation may be smooth, ridged, pitted or reticulate. A single stout spine occurs in the posteroventral region of both valves. Dorsal margin straight; ventral margin convex, drawn out posteriorly into a subdorsal caudal process; anterior end broadly rounded. Marginal area moderately broad, line of concrescence and inner margin coincide throughout. Radial porecanals few and simple in the anterior end and in the caudal process. A few normal pore canals scattered over the surface, causing a pitted appearance. Hingement in the right valve consisting of two terminal, rather strong teeth; immediately behind the anterior tooth a large socket, which is open towards the interior. A serrate groove runs forward from the dorsal side of the posterior tooth, merging into the dorsal wall of the anterior socket. Left valve hinge pattern the complement of the right, with terminal sockets, both of which are open towards the interior. Behind the anterior socket a strong tooth; between the dorsal side of this tooth and the dorsal wall of the posterior socket a finely crenulate bar. Muscle-scar area with a vertical row of four scars, situated on the interior ridge of the sulcus; in the male specimens they are situated more towards the anterior than in the female specimens and they are often hardly visible. Sexual dimorphism pronounced, the males being more elongate and less swollen than the females.

Type species, *N. columbiformis* Kingma. Marine, Recent. Pacific region and Gulf of Mexico.

*Remarks.*—The genus was referred to the subfamily Bythocytherinae Sars, 1926, by Kingma who also placed *Cytherura* in that subfamily. Since the latter is the type of its own subfamily (Cytherurinae), the classification of both these genera is confused and needs further study.

### NEOMONOCERATINA sp.
### Plate 64, figure 15

Shell very small and delicate, subrhomboidal hinge margin straight and about half of shell length; ventral margin nearly straight; anterior margin extended below; posterior margin strongly extended with short caudal process. Left valve larger than right, convexity moderate, greatest midventrally. Terminal areas somewhat compressed and having narrow marginal rim; caudal process strongly compressed; a long slightly oblique median furrow runs from anterodorsal area to a position ventral of midheight; two narrow sinuous longitudinal ridges occur in ventral half; two short curved ridges trend anterodorsally from the posterior portion of the more median longitudinal ridge; general surface, other than impressed marginal zone, bears numerous pits arranged in roughly concentric rows.

Hinge of left valve consists of an anterior deep socket, postjacent pointed tooth, long interterminal bar with dorsally adjacent accommodation shelf and a posterior tooth which is bordered dorsally and on either side by a deep furrow. Right valve hinge not seen. Inner lamellae broad, but with inner margin and line of concrescence not greatly separated; anteriorly it is sinuous and bears a few radial canals. Muscle scar not observed.

Length of figured specimen, a complete shell 0.41 mm., height 0.21 mm., convexity 0.16 mm.

*Remarks.* The pattern of surface ridges and pits distinguish this species from others known to the writer. Kingma's Malayan species have posteroventral spine-like alae. Some North Atlantic species, such as *Cytherura cornuta* Brady and *C. affinis* Sars are similar to the present species in general shape, median sulcus and pitted or reticulate surface, but are different in details of surface ornamentation. The North Atlantic species should probably be referred to *Neomonoceratina*.

*Occurrence.*—The figured specimen is from J5A. Occurs at several other stations in the open Gulf.

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ADDENDUM

The writer recently had an opportunity, through the courtesy of Sohn, to study Brady's descriptions of Recent ostracodes from the West Indies, in Folin and Perier's "Fonds de la Mer." The four volumes of this rare publication are in the Mollusk Library of the U. S. National Museum. *Cythere danaiana* Brady is similar to *Cythere* sp. of this paper. Müller (1912, p. 364) referred *C. danaiana* to *Cythere pumicosa* Brady 1866, another West Indian species.

Howe (Louisiana State Univ. Studies, Phys. Sci. ser. no. 1, 1955, p. 26, 188) pointed out that the large group of ostracodes related to *Candona candida* (Müller) may have to be removed to *Typhlocypris* Vejdovsky or a new genus. *Candona reptans* [later made the type of *Erpetocypris* Brady & Norman] was designated the type of *Candona* by Baird (1846) in a little-known publication. The species referred to *Candona* in this paper may therefore require assignment to another genus.

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 4, PP. 647–664, PL. 65, 3 TEXT-FIGS., JULY 1955

# SOME PLANKTONIC FORAMINIFERA OF THE AMERICAN GULF COAST AND SUGGESTED CORRELATIONS WITH THE CARIBBEAN TERTIARY

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ABSTRACT—Planktonic Foraminifera are proposed as a means of correlating Tertiary deposits of the American Gulf Coast with those of the Caribbean region. The ranges of *Globigerinatella insueta*, *Globorotalia mayeri*, and *Globorotalia fohsi*, and the lower limits of *Orbulina* and *Globorotalia menardii* in the Texas-Louisiana Gulf Coast are concluded to be synchronous with the respective ranges and lower limits of these Foraminifera in the Caribbean-West Indian Tertiary. Twenty-five species and one variety of planktonic Foraminifera are identified in post-Eocene sediments of the Texas-Louisiana Gulf Coast of which four species and one variety have not been described previously.

## INTRODUCTION

INVESTIGATION of the planktonic Foraminifera as a means of establishing both local and interregional time correlations has been urged by numerous stratigraphers. Successful zonation of Tertiary beds in various parts of the world, viz., the Caribbean area, the Middle East, and Sumatra, by means of these floating organisms suggests that some species had more than regional distribution and that their incipience and extinction may have approached universal synchroneity.

Although a number of planktonic species have been described from Gulf Coast Tertiary sediments which are recognized as having stratigraphic significance elsewhere, they and the whole group of drifting Foraminifera have been relatively neglected here. This is particularly true of post-Eocene types, and the following conditions have been offered for their disregard in the Gulf Coast of Texas and Louisiana:

*1. The tendency among early micropaleontologists to overlook the distinctive features of some of the fossil species of* Globigerina *and* Globorotalia *and to identify them with living species.* Grimsdale (1951) has shown that in some cases the early figures of species have proved too minute or too generalized for precise determinations to be achieved from them, "thus rendering the standard of precision too low for proper species delineation in these genera—which are among the most difficult and confusing of Foraminifera by reason of their variability and frequent homeomorphy."

*2. The transition in the American Gulf Coast of subsurface marine Upper Tertiary facies to non-marine, non-globigerinid facies at the outcrops.* Stratigraphic relationships thus cannot be established by means of outcrop material.

*3. The practice in the Gulf Coast of discarding most of the cored material.* Paleontologic and lithologic analyses have been largely dependent upon ditch samples and the "tops" method in which the lower range limit of species cannot be determined accurately.

*4. The nearshore origin of much of the upper Tertiary subsurface section in which globigerinid facies are absent.* The deltaic physiographic features of coastal Louisiana, serving as great seaward ramps, have permitted drilling into the underlying marine facies of Upper Tertiary beds which are of non-marine character up dip and in Texas, but even in these marine sediments planktonic Foraminifera are seldom abundant, and fossil *Globigerina* deposits such as those of the West Indies (Oceanic formation of Barbados; Cipero formation of Trinidad) are unknown. Much of the Tertiary of Louisiana is considered to have been deposited under conditions similar to those which now obtain in the vicinity of the present delta of the Mississippi River. In the offshore waters the planktonic Foraminifera, though present, are not abundant except at a distance of several miles from the passes, ostensibly in preference for undiluted sea water, as concluded by Parker (1948).

*5. The presence of easily identifiable benthonic index Foraminifera.* These are always present in those facies which contain abundant planktonic types as well as in other facies, and they have been employed so extensively in stratigraphic problems that their names are already well established in the literature. The benthonic species have long been significant aids in problems of depositional environment and local stratal correlation. Thus, some paleontologists have believed that little is to be gained in local geologic projects by the delineation of additional guide fossils.

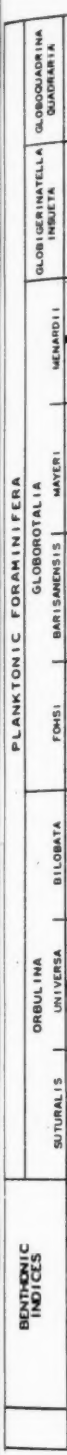
This investigation of planktonic Foraminifera in the later Cenozoic sediments of the Gulf Coast was undertaken largely out of curiosity as to the presence and significance of guide fossils which are valuable in other regions. Detailed studies of cored samples from the *Heterostegina* zone to Recent beds were made in order to determine the lower limits of species as well as "tops." Recent samples were collected off the Louisiana coast, and their examination extends our information upon the planktonic Foraminifera in this area to modern times. The ranges and coiling preferences of several planktonic species common to the Gulf Coast and the Caribbean area appear to be analogous, suggesting that contemporaneous deposition occurred in these regions, that movement of water masses between them was unrestricted, and that surface temperatures were essentially the same.

Mr. R. J. Drury and Mr. E. J. Larmeu of The California Company assisted in the laboratory preparation of samples. Dr. W. A. van den Bold of United British Oil Fields of Trinidad, and Mr. Harold Kaska, Dominion Oil Limited, Trinidad, B.W.I., examined typical material and compared it with that of Trinidad. Mr. Kaska also supplied the writer with Tertiary samples from Trinidad. Dr. P. Bronnimann, Cuban Gulf Oil Company, gave helpful suggestions. The California Company supported the study and gave permission for its publication.

## INTERREGIONAL CORRELATIONS AND COMPARISONS OF FORAMINIFERAL RANGES

Time correlations within the Tertiary are indicated between the American Gulf Coast and the Caribbean area by the ranges and evolution of several planktonic foraminiferal species which are common to both regions. The present correlation between the Texas-Louisiana Gulf Coast Tertiary sequence and the west European and Mediterranean type successions, on the other hand, has been compiled largely without reference to the Foraminifera, planktonic or benthonic, and since similar references have been made of the Caribbean sequence to the west European-Mediterranean Tertiary deposits, it is not surprising that certain discrepancies exist between the Gulf Coast and the Caribbean geologic columns. Foraminifera indicate, for example, that much of the Trinidad section referred to the upper Oligocene is correlative in time with sediments of the Gulf Coast which are referred to middle and upper Miocene. The planktonic sequences discussed below and shown in Text-fig. 1 (compare with Bronnimann, 1951, text-fig. 1, p. 131) seem to possess interregional time significance irrespective of their present allocated chronologic position according to European terminology.

*1. The* Globigerinatella insueta *zone of Trinidad.*—Bronnimann (1950, pp. 80–82) has adequately discussed the occurrence and ontogeny of *Globigerinatella insueta* Cushman and Stainforth in the Oligocene of Trinidad, where it is diagnostic for Zone II (Cushman and Stainforth, 1945, p. 4) of the Cipero marl formation. He also reports its presence at the type locality of the Ste. Croix calcareous clay. Stainforth (1948a, p. 120; 1948b, pp. 1327–1328) reported *G. insueta* from the upper Oligocene of the Oceanic formation of Barbados and from the late middle and early upper Oligocene of Ecuador. Renz (1948, p. 136) records it as scarce in and restricted to the lower part of the upper Acostian of the Agua Salada Group, State of Falcón, Venezuela, and Cushman and Renz (1947, p. 41) have found it at the type locality of the Trinidad Point calcareous clay at Trinidad Point, Oropauche Lagoon, southern Trinidad. In coastal Louisiana Tertiary sediments, the species is extremely rare, but the writer has found several specimens in cores from the *Amphistegina* and *Operculinoides* zones in association with *Globorotalia mayeri* and *Globoquadrina quadraria.* As in Trinidad, the occurrence is below the first appearance of



TEXT-FIG. 1—Stratigraphic distribution of some planktonic Foraminifera in the Texas-Louisiana Gulf Coast.

*Orbulina* and *Globorotalia fohsi fohsi*, and it is this sequence of appearances that suggests the synchroneity of the range of *Globigerinatella insueta* in Louisiana with its range in the Caribbean area.

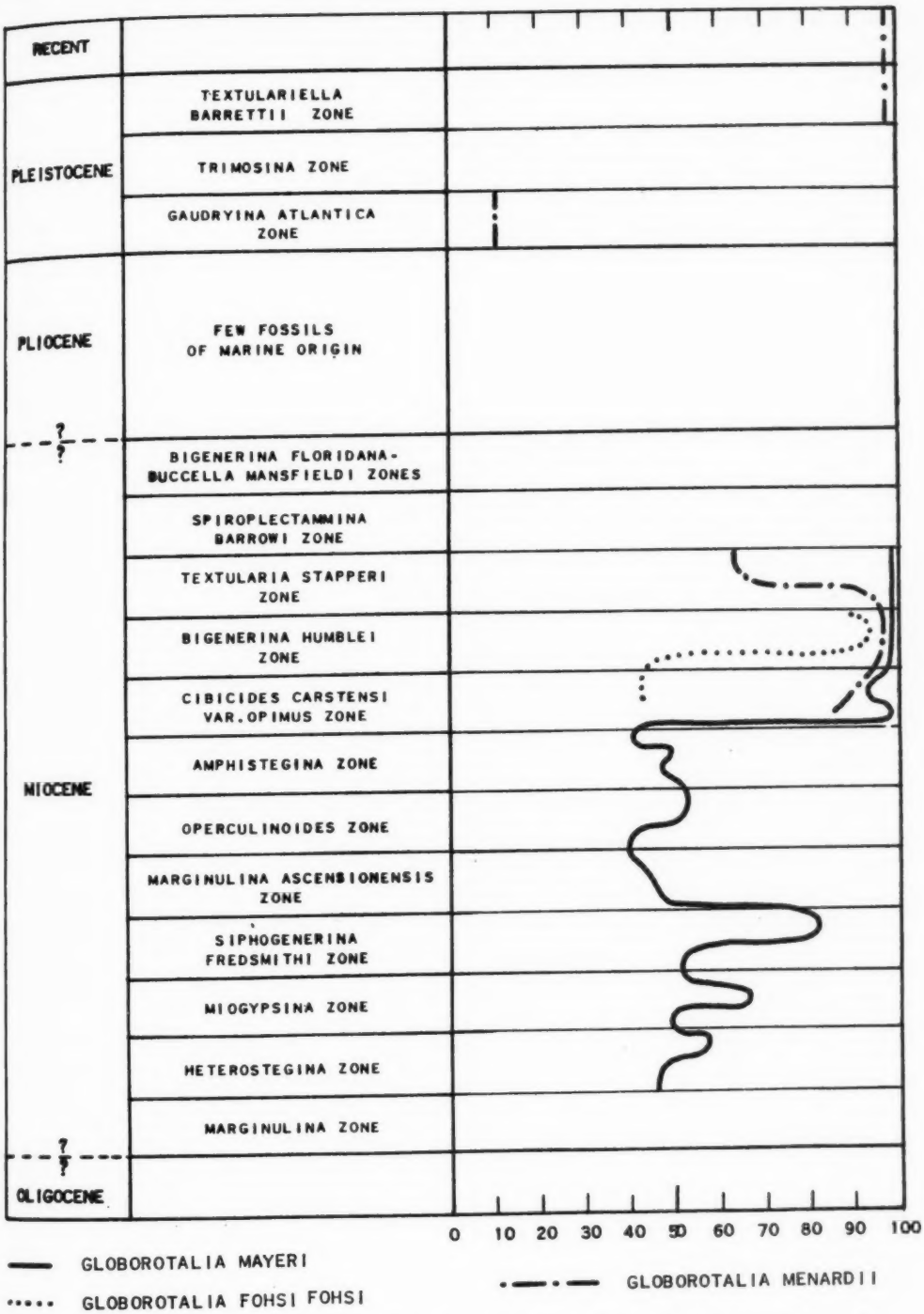
*2. The range of* Globorotalia mayeri *in the Gulf Coast and in Trinidad.—Globorotalia mayeri* was originally described from a coastal Louisiana Tertiary core sample (Cushman and Ellisor 1939, p. 11). It became extinct here shortly after *Globorotalia fohsi fohsi*, although its first appearance, as in Trinidad (Bolli, 1950, p. 84; Bronnimann, 1951, p. 131), was considerably earlier. Bermúdez (1949, p. 286) reports that the species is widely distributed in deep-water deposits between the middle and upper Oligocene in the Dominican Republic. He found it to be frequent in the middle Oligocene, Sombrerito formation. The writer has identified *G. mayeri* in Miocene ditch samples from several wells in Cameron County, Texas, as well as in numerous cores from the "Miocene" of Louisiana. As in Trinidad, this species has a comparatively long range coinciding in part with the other most commonly occurring planktonic Foraminifera (Text-fig. 1; Bronnimann, 1951, text-fig. 1, p. 131). The synchroneity of its range in Trinidad with its range in the Gulf Coast is further indicated by the direction of coiling. Bolli (1950, p. 84) describes this in the Cipero formation of Trinidad as follows:

"Early specimens of *Globorotalia mayeri* in the *Globigerina dissimilis* and *Globigerinatella insueta* zones show sinistral and dextral coiling in about equal proportion, whereas a rapid change towards 95 per cent or more of sinistral coiling has been observed in the higher subzones of the *Globorotalia fohsi* group."

This change from the random coiling of the early representatives of the species to a preferred sinistral direction by the stratigraphically younger ones is paralleled in the Louisiana Miocene (see Text-fig. 2). The quantitative methods of Bolli (1951, p. 140) were employed and show that the oldest specimens, which are found in the *Heterostegina* zone, are coiled in either direction with approximately equal frequency. A sharp change takes place, however, in the *Cibicides carstensi* var. *opimus* zone, and the species preferred sinistral coiling throughout its final occurrence in the *Textularia stapperi* zone.

The lower limit of the range of *Globorotalia mayeri* in the American Gulf Coast approximates the stratigraphic position of the upper limit of *Heterostegina* spp. (Text-fig. 1). Bermúdez (1949, p. 172) has identified specimens of *Heterostegina* in limestone samples of middle Oligocene age in the Dominican Republic and also gives the middle Oligocene as the lower limit of *Globorotalia mayeri* (p. 286). Stainforth (1948, p. 1311) and others have listed *Heterostegina antillea* Cushman among the Foraminifera of the Mejas limestone of Trinidad to which Suter (1951, table 4) gives a *Globigerinatella insueta* age. *Globorotalia mayeri*, according to Bronnimann (1951, text-fig. 1, p. 131), has its lower limit in approximation with the lower limit of the *Globigerinatella insueta* zone in Trinidad. This evidence and other records of the uppermost Tertiary occurrence of *Heterostegina* in the Gulf of Mexico-Caribbean region (Renz, 1948, p. 142; Galloway and Heminway, 1941, p. 442) point to a sudden change, possibly in temperature, during the Tertiary which effected an abrupt synchronous disappearance of members of this warm water genus from the region.

*3. The* Globorotalia fohsi *zone of the Caribbean and the Gulf Coast. Globorotalia fohsi* was originally described from a coastal Louisiana Miocene core (Cushman and Ellisor, 1939, p. 12). Lately it has been recognized as an excellent marker for beds considered to be upper Oligocene in age in the Caribbean-West Indian region. Bermúdez (1949, pp. 285–286) has found it in deep-water sediments between the middle Oligocene and the upper Miocene in the Dominican Republic, usually associated with *Globorotalia mayeri* Cushman and Ellisor. The type locality for the *Globorotalia fohsi* zone, Pozon formation, Agua Salada group, has been chosen by Renz (1948, pp. 56–59) at Pozon, State of Falcón, Venezuela, where he has found this species to be characteristic of the foraminiferal assemblages. He suggests that this zone is correlative with the *Globorotalia fohsi* zone (Zone III) of the Cipero marl formation in Trinidad, as described by Cushman and Stainforth (1945, pp. 5–6), and with that part of the Cojimar




TEXT-FIG. 2—Percentage of sinistral coiling of some globorotalias in the Tertiary of Louisiana.

formation of Cuba from which Palmer (1941, p. 291) has identified the species. Renz (1948, p. 59) has also found the species in well samples from Barbados. Bolli (1950, p. 84) considered the species diagnostic for the Trinidad upper Oligocene and selected it "as the central type of the superspecies with the name *Globorotalia fohsi fohsi* Cushman and Ellisor." Specimens from Louisiana and Cameron County, Texas, appear to be identical with his *G. fohsi fohsi*.

Bolli's proposed subspecies may be listed in descending stratigraphic order as follows:

*Globorotalia fohsi robusta* Bolli
*Globorotalia fohsi lobata* Bermúdez
*Globorotalia fohsi fohsi* Cushman and Ellisor
*Globorotalia fohsi barisanensis* LeRoy

*Globorotalia fohsi robusta* has not been identified in the American Gulf Coast, nor has *Globorotalia fohsi lobata* previous to this writing. The writer has found specimens of both *G. fohsi lobata* and *G. fohsi fohsi* in ditch samples from the marine beds considered to be Miocene in age of Cameron County, Texas. The specimens of *G. fohsi lobata* are typical and apparently occur higher stratigraphically in this area than *G. fohsi fohsi*, although it is undesirable to state such a conclusion as fact without confirmation by cored material. In Louisiana only *G. fohsi fohsi* and *G. fohsi barisanensis* have been identified, but their ranges are known with certainty by means of cored samples. *G. fohsi fohsi* first appeared in the *Planulina harangensis* zone and became extinct at approximately the end of *Bigenerina humblei* time, whereas *G. fohsi barisanensis* became extinct earlier near the end of *Cibicides carstensi* var. *opimus* time (Text-fig. 1). Further indication of the synchroneity of the *Globorotalia fohsi* zone of Trinidad with the *Bigenerina humblei-Cibicides carstensi* var. *opimus* section of Louisiana may be seen in a comparison of the coiling of the *Globorotalia fohsi* group in the Oligocene Cipero formation (Bolli, 1950, text-fig. 2) with the coiling of *G. fohsi fohsi* throughout its range in the Louisiana Miocene (Text-fig. 2). As in Trinidad, coiling within the superspecies is random in the early part of its range, rising to over 90 per cent in favor of sinistral coiling before extinction.

*4. The* Orbulina *surface in Louisiana and the Caribbean region.* In the Gulf Coast the first occurrence of the genus *Orbulina* is in the *Planulina harangensis* zone of the Miocene. This is also the lowest zone in which the writer has found *Globorotalia fohsi fohsi*. Numerous fossiliferous cores from lower beds, many of them rich in other planktonic Foraminifera, were examined for the "*Orbulina* surface" which has been proposed by Tromp (1941, 1949) and LeRoy (1948, 1952) as a world wide Middle Tertiary time datum. In Trinidad the first representatives of *O. suturalis* appeared abruptly in the lower part of the *Globorotalia fohsi* zone (Bronnimann, 1951, p. 136). Cushman and Stainforth (1945, p. 69) had previously recorded the first appearance of *Candorbulina universa* in the *Globorotalia fohsi* zone of the upper Oligocene Cipero marl formation of Trinidad. The *Orbulina* surface of the Gulf Coast and that of Trinidad appear to be synchronous, especially when the ranges of other planktonic species common to the two areas are compared (Text-fig. 1 and Bronnimann, 1951, p. 131). In both areas *Orbulina suturalis* appeared shortly after the extinction of *Globigerinatella insueta*, just before the appearance of *Globorotalia menardii*, and at approximately the same time as *Globorotalia fohsi fohsi*.

Less evidence is available at present, however, for the synchroneity of the "*Orbulina* surface" of the Gulf Coast and Trinidad with the earliest recorded appearance of the genus in the deep water deposits of the Trinchera and Sombrerito formations of Santo Domingo and the marls of the Jaruco formation of Cuba (Bermúdez, 1949, p. 282; 1950, stratigraphical chart, pp. 351–352).

*5. The first appearance of* Globorotalia menardii. The present investigation suggests that *Globorotalia menardii* may, like *Orbulina universa*, have worldwide time significance. The stratigraphic position of its first appearance with respect to the ranges of other planktonic Foraminifera indicates that its base in the American Gulf Coast is time-correlative with its first appearance in the Trinidad material (Text-fig. 1 and Bronnimann, 1951, text-fig. 1, p. 131). The lowermost occurrence of *Globorotalia menardii* in

Florida is in the Shoal River formation (Cushman and Cahill, 1933, p. 34) and is approximately synchronous with its advent in the Harang sediments of Louisiana. The one specimen of questionable identification reported from the Marianna material (Cole and Ponton, 1930, p. 45) is not considered adequate evidence of a pre-Shoal River occurrence. It is suggested that the following additional occurrences of *Globorotalia menardii* may have time significance irrespective of present allocated chronologic position according to European terminology:

Jamaica, Bowden formation (Palmer, 1945, pp. 70–71).
Haiti, strata near Port-au-Prince (Coryell and Rivero, 1940, p. 336).
Dominican Republic, deep-water deposits between the middle Oligocene and the upper Miocene (Bermúdez, 1949, pp. 286–287).
Puerto Rico, Quebradillas formation (Galloway and Heminway, 1941, pp. 368).
Costa Rica, Uscari shale (Palmer, 1923, p. 9).
Venezuela, Pozon formation, *Globorotalia fohsi* zone (Renz, 1948, p. 137).
Cuba, marl near Matanzas (Hadley, 1934, p. 25).

The species is known to occur stratigraphically higher in all of the above areas, but if the above beds contain the lowermost occurrence of correctly identified representatives, it is possible that further studies will indicate a closer time-wise relationship of these deposits than has been hitherto suspected.

The frequency curve of the direction of coiling of *Globorotalia menardii* in the Louisiana Cenozoic is interesting (Text-fig. 2). The earliest forms coiled over 80 per cent sinistrally, but in the *Textularia stapperi* zone sinistral preference had decreased to almost 60 per cent. Few specimens are found in the higher Tertiary beds because of their nonmarine and inshore origin, but in marine sediments of lower Pleistocene age the preference for sinistral coiling had further decreased to approximately 10 per cent. An abrupt change occurred later during the Pleistocene, because in upper Pleistocene and Recent marine sediments the preference is over 95 per cent in favor of sinistral coiling.

*Globorotalia praemenardii* Cushman and Stainforth has not been identified in the American Gulf Coast.

## CONCLUSIONS

Presently allocated chronologic positions of many Tertiary deposits of the Gulf Coast-Caribbean region are probably incorrect because of the difficulty of establishing comparisons with the European standard and the unreliability of age determinations which are based on a comparison of percentages of Recent species in the faunal assemblages. These difficulties arise because of insufficient knowledge of Recent faunas, different personal opinions as to correct specific identification, and the influence upon faunal distribution by ecologic factors. Age determinations based on the known stratigraphic ranges of species appear to have given the most reliable results (Drooger, 1953, p. 118). Species which are planktonic by habit during at least part of their life cycle are ideal zone-fossils for long-range correlation because of their ubiquity and relative independence of ecologic conditions on the sea-bottom. According to LeRoy (1952, p. 576) the following qualifications must be met by the interregional time indicator: "(1) proper biotic facies, (2) continuous sedimentation during the time interval in which the species was first biologically introduced into the geologic column, and (3) rapid geographic dispersal of the genus at the time of biologic initiation." In the Gulf Coast-Caribbean region the following planktonic zones or ranges and levels of lowest stratigraphic occurrence seem to be in accord with such conditions:

1. The *Globigerinatella insueta* zone.
2. The range of *Globorotalia mayeri*.
3. The *Globorotalia fohsi* zone.
4. The lower limit of *Orbulina*.
5. The lower limit of *Globorotalia menardii*.

Besides a contemporaneity of deposition in the "American Mediterranean," unrestricted movement of water masses and uniform surface temperatures must have existed during the time intervals represented by correlative planktonic sequences.

Although long-range correlations may be established by means of the planktonic Foraminifera or other organisms which are

so unaffected by bottom environment as to be "facies free," satisfactory allocation of deposits to chronologic position according to European terminology can only be accomplished by a detailed study of and correlation with similar "facies free" elements in sediments at the European type localities.

## SYSTEMATICS

### Family HETEROHELICIDAE
### Genus GÜMBELINA Egger, 1899
### GÜMBELINA CUBENSIS D. K. Palmer

*Gumbelina cubensis* D. K. PALMER, 1934, Soc. cubana hist. nat. Mem., vol. 8, p. 74, text figs. 1–6; CUSHMAN, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 63, pl. 10, fig. 54; BERGQUIST, 1942, Mississippi Geol. Survey Bull. 49, p. 62, pl. 6, figs. 26, 27; CUSHMAN and HERRICK, 1945, Cushman Lab. Foram. Research Contr., vol. 21, p. 63, pl. 10, fig. 14; CUSHMAN, 1946, Cushman Lab. Foram. Research Special Pub. 16, p. 22, pl. 4, fig. 28; CUSHMAN and TODD, 1946, Cushman Lab. Foram. Research Contr., vol. 22, p. 90; 1948, Cushman Lab. Foram. Research Contr., vol. 24, p. 11 (list); RENZ, 1948, Geol. Soc. America Mem. 32, p. 138, pl. 6, fig. 9; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 175, pl. 11, fig. 40; TODD, 1952, U. S. Geol. Survey Prof. Paper 241, p. 24, pl. 4, fig. 1; HAMILTON, 1953, Jour. Paleontology, vol. 27, p. 234.

This species is rarely found in ditch samples because of its minute size. Most specimens pass through a no. 120 screen (U. S. Standard Sieve Series). The species was found in abundance on a no. 200 screen in cores from the interval just below the top of the *Nodosaria blanpiedi* zone at Gillis Field, Calcasieu Parish, and Plumb Bob Field, St. Martin Parish, Louisiana. The facies in both cases was of marine character and was distinguished by an abundance of globigerinids. This may be the upper limit of the range of the genus in the American Gulf Coast, which has not been previously established due to the shallow water or nearshore origin of many of the later Tertiary strata at the outcrop. *G. cubensis* has been identified in the lower Araguatian and questionably in the upper Acostian of El Mene de Acosta, Venezuela. The species occurs commonly throughout the Byram formation (Vicksburg group) of Mississippi. It has been found in the Oligocene and upper Eocene of Cuba and the Dominican Republic, the upper Oligocene of several mid-Pacific seamounts, the Eocene of submarine cores off the east coast of the United States, the Eocene of Mississippi, Alabama, and Georgia, and the Oligocene Byram formation and Red Bluff clay of Mississippi.

### Family GLOBIGERINIDAE
### Genus GLOBIGERINA d'Orbigny, 1826
### GLOBIGERINA BULLOIDES d'Orbigny

*Globigerina bulloides* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 277; Modèles, nos. 17, 76; PALMER, 1941, Soc. cubana hist. nat. Mem., vol. 15, p. 285; 1945, Bull. Am. Paleontology, vol. 29, no. 115, p. 67; CUSHMAN and STAINFORTH, 1945, Cushman Lab. Foram. Research Special Pub. 14, p. 68, pl. 13, fig. 4; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 278, pl. 21, fig. 49; PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 34, pl. 19, figs. 6, 7.

Specimens logically grouped with this form are found throughout the Louisiana Neogene and in Tertiary beds of Cuba, Jamaica, the Dominican Republic, and Trinidad. The species is present in Recent sediments of the Gulf of Mexico-Caribbean region as well as in other marine waters of the world.

### GLOBIGERINA DRURYI Akers, n. sp.
### Plate 65, figures 1A–1C

Test small, trochoid, largely composed of two convolutions, the last of which consists of four subglobular chambers; periphery broadly rounded and lobate; wall coarsely perforate; aperture a small low arch with a thin upper lip at the base of the last chamber. Height of holotype, 0.28 mm.; width, 0.26 mm.; thickness, 0.20 mm.

Holotype No. 106 from the Miocene *Cibicides carstensi* var. *opimus* zone (core 11,257–11,267 feet) of Humble Oil and Refining Company Ellender No. 1, Section 23, Township 19 South, Range 19 East, Lirette Field, Terrebonne Parish, Louisiana. Deposited in the California Company Collection, New Orleans, Louisiana.

The small size, distinctly small aperture, and coarse perforations serve to distinguish this species from others of the genus. Named for Mr. R. J. Drury of the California Company. It is a valuable index fossil in the *Cibicides carstensi* var. *opimus* zone.

GLOBIGERINA DUBIA Egger

*Globigerina dubia* EGGER, 1857, Neues Jahrb. Min., Geogn., Geol., Petref.-Kunde, Jahr. 1857, p. 281, pl. 9, figs. 7–9; H. B. BRADY 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 595, pl. 79, fig. 17; FLINT, 1899, U. S. Nat. Mus. Ann. Rept. (1897), pt. 1, p. 322, pl. 69, fig. 4; PHLEGER, 1939, Geol. Soc. America Bull., vol. 50, p. 1404, pl. 1, figs. 14, 15.

*Globigerina eggeri* Rhumbler. PARKER, 1948, Harvard Coll. Mus. Comp. Zoology Bull., vol. 100, no. 2, pl. 7, figs. 5, 6; PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 34, pl. 19, figs. 8, 9.

*Globigerina conglomerata* Schwager. CUSHMAN, 1941, Am. Jour. Sci., vol. 239, no. 2, pl. 1, fig. 3; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 278, pl. 21, figs. 41, 42.

Specimens have been grouped with this species which show some variation in chamber inflation, number of chambers in the last-formed whorl, and height of spire. The species should be considered as a "species group" (Phleger and Parker, 1951, p. 33), and intensive study of large quantities of sediments of various ages and from various localities may justify its division. Forms assigned to the group are abundant in Recent samples of the northern Gulf of Mexico and in the lower Pleistocene and Tertiary of the American Gulf Coast.

Genus GLOBIGERINITA Bronnimann, 1951

GLOBIGERINITA INCRUSTA Akers, n. sp.

Plate 65, figures 2A–2D

Test very small, trochoidal; spire with three whorls. Chambers subglobular, gradually increasing in size, non-enveloping. Adult with four large and well separated subglobular chambers. Initial chamber very minute, usually not visible. Umbilical region of adult covered with a single, irregularly shaped, rather thin and smooth supplementary chamber which branches out into the sutural grooves. Aperture of adult multiple consisting of a small semicircular opening at the end of each branch of the supplementary chamber. Apertures of chambers formed prior to the supplementary chamber are single, small semicircular openings. Walls are finely perforate. Height of holotype, 0.16 mm.; width, 0.14 mm.; thickness, 0.11 mm.

Holotype No. 102 from the Miocene *Cibicides carstensi* var. *opimus* zone (core 10,132–10,142 feet) of Humble Oil and Refining Company Ellender No. 1, Section 23, Township 19 South, Range 19 East, Lirette Field, Terrebonne Parish, Louisiana. Deposited in the California Company Collection, New Orleans, Louisiana.

This species differs from *Globigerinita naparimaensis* Bronnimann in its consistently smaller size; in having openings only at the ends of branches of the supplementary chamber instead of along the sutures of the supplementary chamber; and in having a much smaller aperture in the *Globerigerina* chambers formed prior to the supplementary growth. It differs from *Globigerinita glutinata* (Egger) in having fewer openings of the supplementary chamber and in the confinement of these openings to ends of branches of the supplementary chambers.

Genus GLOBIGERINELLA Cushman, 1927

GLOBIGERINELLA AEQUILATERALIS (H. B. Brady)

*Globigerina aequilateralis* (H. B. BRADY), 1879, Quart. Jour. Micr. Sci., vol. 19, p. 71; 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 605, pl. 80, figs. 18–21; FLINT, 1899, U. S. Nat. Mus. Ann. Rept. (1897), pt. 1, p. 323, pl. 70, fig. 3; CUSHMAN, 1924, U. S. Nat. Mus. Bull. 104, pt. 5, pl. 4, figs. 7, 8.

*Globigerinella aequilateralis* (Brady). PHLEGER, 1939, Geol. Soc. America Bull., vol. 50, p. 1405, pl. 1, figs. 11, 13; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 280, pl. 21, fig. 51; PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 35, pl. 19, fig. 14.

Few typical specimens have been found in Gulf Coast Recent or Tertiary sediments. Most specimens referred to this species are bilaterally asymmetrical but include the typical form within their range of variation. Specimens were not found to be abundant in any of the Louisiana cores, and they constitute a minor part of the Tertiary planktonic faunas as in modern seas (Kane, 1953, p. 35).

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES CONGLOBATUS (H. B. Brady)

*Globigerina conglobata* H. B. BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, p. 72; 1884, Rept. Voy.

Challenger, Zool., vol. 8, p. 603, pl. 80, figs. 1–5; CUSHMAN, 1924, U. S. Nat. Mus. Bull. 104, pt. 5, p. 18, pl. 3, figs. 8–13; FLINT, 1899, U. S. Nat. Mus. Ann. Rept. (1897)), pt. 1, p. 322, pl. 69, fig. 6.

*Globigerinoides conglobata* (H. B. Brady). BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 280, pl. 21, fig. 46; PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 35, pl. 19, fig. 15.

This species is present in Recent sediments of the Gulf of Mexico and in marine Pleistocene material of coastal Louisiana. It was rare in the Tertiary material examined. Bermúdez (1949, p. 280) records it in the Miocene of the Dominican Republic.

### GLOBIGERINOIDES RUBER (d'Orbigny)

*Globigerina rubra* D'ORBIGNY, 1839, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 82, pl. 4, figs. 12–14; CUSHMAN, 1924, U. S. Nat. Mus. Bull. 104, pt. 5, p. 15, pl. 3, figs. 4–7.

*Globigerinoides rubra* (d'Orbigny). D. K. PALMER, 1945, Bull. Am. Paleontology, vol. 29, no. 115, p. 68; CUSHMAN and TODD, 1945, Cushman Lab. Foram. Research Special Pub. 15, p. 66, pl. 11, fig. 13; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 281, pl. 21, fig. 52; PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 35, pl. 19, fig. 16.

Forms assigned to this "species group" are the most abundant planktonic species in most offshore Lousisana Recent samples. It was also found to be the dominant planktonic species in all of the marine Pleistocene and Tertiary core samples.

### GLOBIGERINOIDES SACCULIFER (H. B. Brady)

*Globigerina sacculifera* H. B. BRADY, 1877, Geol. Mag., dec. 2, vol. 4, p. 535; 1879, Quart. Jour. Micr. Sci., vol. 19, p. 73; 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 604, pl. 80, figs. 11–17; CUSHMAN, 1924, U. S. Nat. Mus. Bull. 104, pt. 5, p. 21, pl. 4, figs. 1–6.

*Globigerinoides sacculifera* (H. B. Brady). CUSHMAN and JARVIS, 1930, Jour. Paleontology, vol. 4, 1930, p. 336, pl. 34, fig. 4; CORYELL and RIVERO, 1940, Jour. Paleontology, vol. 14, p. 340, pl. 42, figs. 24, 25, 32; D. K. PALMER, 1945, Bull. Am. Paleontology, vol. 29, no. 115, p. 68; CUSHMAN and TODD, 1945, Cushman Lab. Foram. Research Special Pub. 15, p. 66, pl. 11, fig. 14; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 281, pl. 21, fig. 53; PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 35, pl. 19, figs. 17–18.

Specimens from lower Pleistocene cores are identical with those in Recent sediments off the coast of Louisiana, and forms differing mainly in size are abundant in many of the Tertiary cores. The American Tertiary forms are smaller than those of the Quarternary but have the typical chamber-sphericity of their descendents. Coiling preference of members of this "species group" has varied between approximately 50 per cent sinistral to approximately 90 per cent sinistral (Text-fig. 3).

## Genus GLOBIGERINATELLA Cushman and Stainforth, 1945

### GLOBIGERINATELLA INSUETA Cushman and Stainforth

*Globigerinatella insueta* CUSHMAN and STAINFORTH, 1945, Cushman Lab. Foram. Research Special Pub. 14, p. 69, pl. 13, figs. 7–9; CUSHMAN and RENZ, 1947, Cushman Lab. Foram. Research Special Pub. 22, p. 41; STAINFORTH, 1948a, Jour. Paleontology, vol. 22, no. 2, p. 120, pl. 26, figs. 16, 17; 1948b, Am. Assoc. Petroleum Geologists Bull., vol. 32, no. 7, p. 1328; RENZ, 1948, Geol. Soc. America Mem. 32, p. 136; BRONNIMANN, 1950, Cushman Found. Foram. Research Contr., vol. 1, pts. 3 and 4, pp. 80–82, pl. 13, figs. 1–12; pl. 14, figs. 1–13.

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### EXPLANATION OF PLATE 65

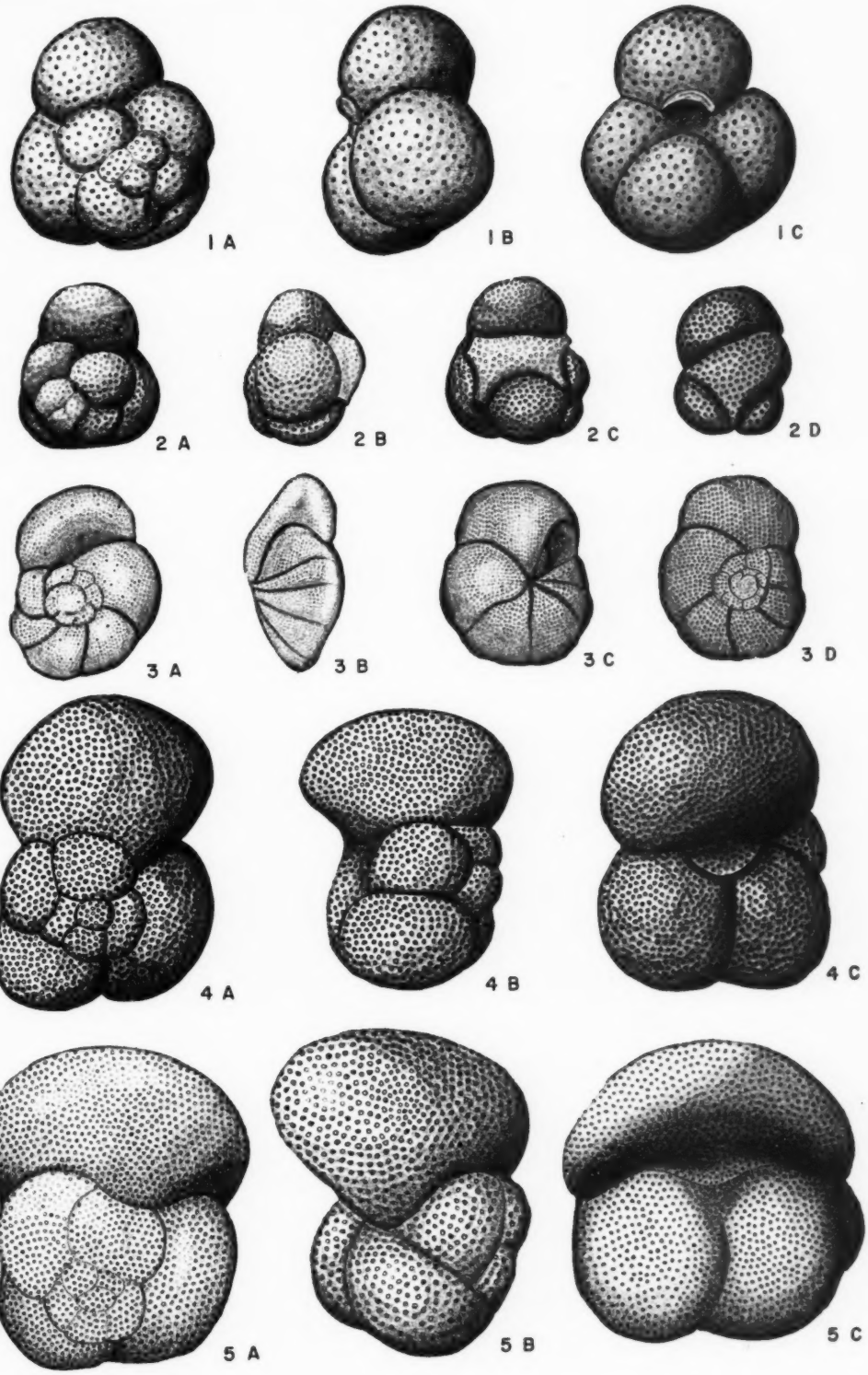
FIGS. 1—*Globigerina druryi* Akers, n. sp. Holotype, ×105. *1A*, Dorsal view; *1B*, edge view; *1C*, ventral view. (p. 654)

2—*Globigerinita incrusta* Akers, n. sp. ×143. *2A–C*, Holotype. *2A*, Dorsal view; *2B*, edge view; *2C*, ventral view; *2D*, Ventral view of another specimen. (p. 655)

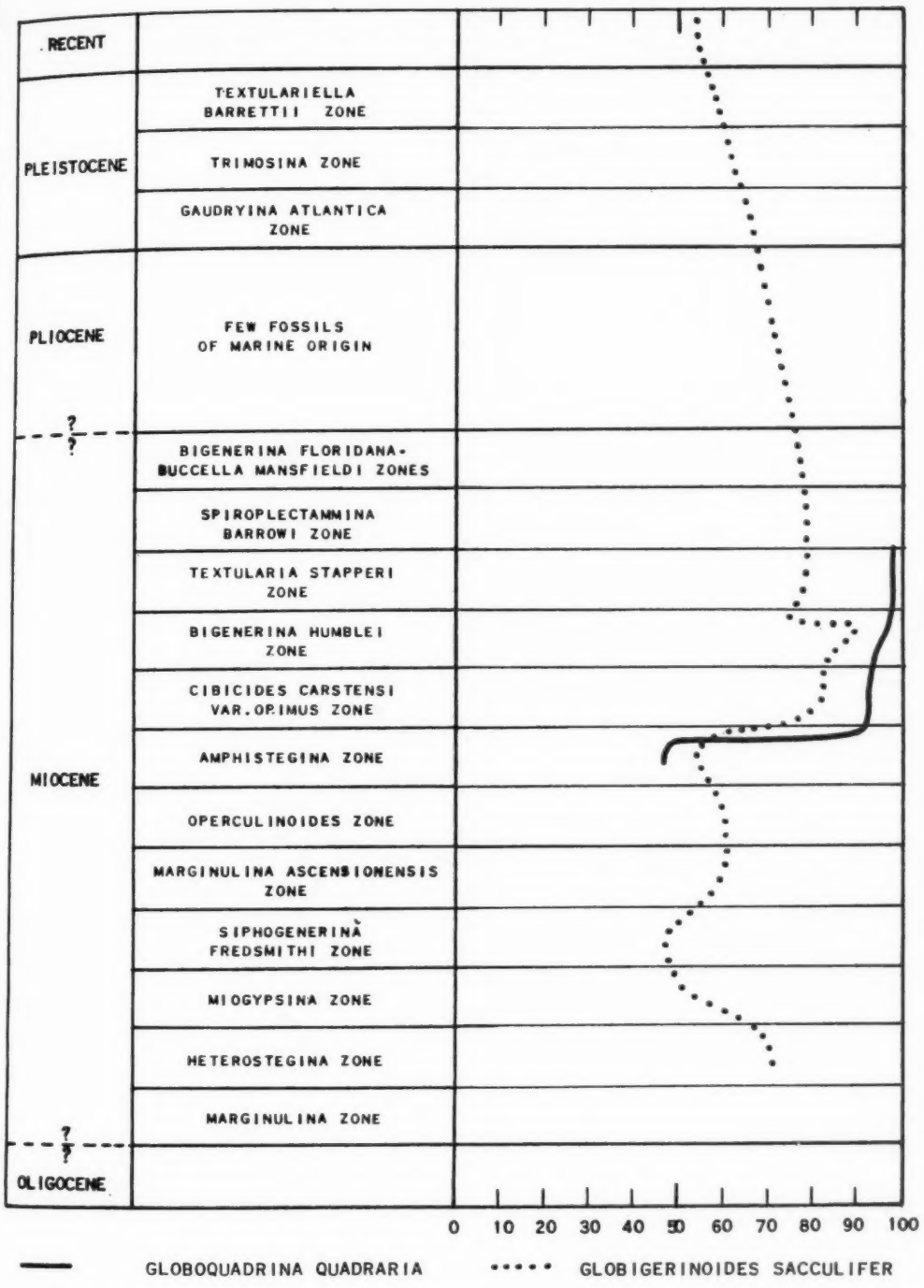
3—*Globorotalia canariensis* (d'Orbigny) var. *minima* Akers, n. var. ×118. *3A–C*, Holotype. *3A*. Dorsal view; *3B*, edge view; *3C*, ventral view; *3D*, Dorsal view of a dextral specimen. (p. 659).

4—*Globoquadrina larmeui* Akers, n. sp. Holotype, ×120. *4A*, Dorsal view; *4B*, edge view; *4C*, ventral view. (p. 661)

5—*Globoquadrina obesa* Akers, n. sp. Holotype, ×125. *5A*, Dorsal view; *5B*, edge view; *5C*, ventral view. (p. 661)




Akers, American Gulf Coast Foraminifera




TEXT-FIG. *3*—Percentage of sinistral coiling of some Globigerinidae in the Tertiary of Louisiana.

This species is rare in the Gulf Coast Tertiary. Specimens were identified in the *Amphistegina* and *Operculinoides* zones (Text-fig. 1) of Shell Godchaux Sugars No. 1, Section 97, Township 11 South, Range 7 East, St. John the Baptist Parish, Louisiana.

### Genus ORBULINA d'Orbigny, 1839
### ORBULINA BILOBATA (d'Orbigny)

*Globigerina bilobata* D'ORBIGNY, 1846, Foraminifères Fossiles du Bassin Tertiaire de Vienne, p. 164, pl. 9, figs. 11–14.
*Globigerina bipartita* REUSS, 1863, Acad. royale sci. Bruxelles Bull., ser. 2, vol. 15, p. 156, pl. 3, fig. 46.
*Globigerina ovoidea* SEGUENZA, 1880, R. acadc. Lincei Mem., vol. 6, p. 334, pl. 17, fig. 39.
*Orbulina universa* (d'Orbigny). H. B. BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 608, pl. 81, fig. 2.
*Orbulina gemina* TERRIGI, 1891, Descr. Carta Geol. Ital. Mem., vol. 4, pt. 1, p. 103.
*Candeina bilobata* JEDLITSCHKA, 1934, Naturf. Ver. Brünn Verh., vol. 65, pp. 22, 24, figs. 8–12.
*Candeina trilobata* JEDLITSCHKA, 1934, Naturf. Ver. Brünn Verh., vol. 65, pp. 22, 24, figs. 14–18, 20.
*Orbulina universa* var. *bisphaerica* LEROY, 1941, Colorado School of Mines Quart., vol. 36, no. 1, p. 44, pl. 1, fig. 3.
*Orbulina bilobata* (d'Orbigny), D. K. PALMER, 1941, Soc. cubana hist. nat. Mem., vol. 15, p. 286, pl. 28, fig. 3; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 282, pl. 22, fig. 4; BRONNIMANN, 1951, Cushman Found. Foram. Research Contr., vol. 2, pt. 4, pp. 135–136, text-fig. 3, figs. 1, 2, 9–10, 17, 19; text-fig. 4, figs. 5, 6, 17–18.

In the American Gulf Coast *Orbulina bilobata* first appeared in the *Planulina harangensis* zone (Text-fig. 1). It is also found in the fossiliferous marine shales of the *Bigenerina humblei* and *Cibicides carstensi* var. *opimus* zones where it is associated with *Orbulina suturalis* and other planktonic species. As in Cuba and Santo Domingo (Bermúdez, 1949, p. 282; 1950, stratigraphical chart, pp. 351–352), the spherical forms are more abundant than the bilobed specimens. Although both *O. universa* and *O. bilobata* have been reported in the Recent of Cuba and Santo Domingo (Brady, 1884, p. 608), abundant *O. bilobata* was not seen in Recent or Pleistocene globigerinid-rich deposits of coastal Texas and Louisiana. As in Trinidad (Bronnimann, 1951, p. 135), no true trilobate individuals have been encountered in any of the Gulf Coast material, although a great many samples were investigated.

### ORBULINA SUTURALIS Bronnimann

*Orbulina universa* d'Orbigny of various authors (not D'ORBIGNY, 1839).
*Candorbulina universa* JEDLITSCHKA, 1934, Naturf. Ver. Brünn Verh., vol. 65, p. 21.
*Candeina triloba* JEDLITSCHKA, 1934, Naturf. Ver. Brünn Verh., vol. 65, p. 24, text fig. 13.
*Orbulina suturalis* BRONNIMANN, 1951, Cushman Found. Foram. Research Contr., vol. 2, pt. 4, p. 135, text-fig. 3, figs. 3–8, 11, 13–16, 18, 20–22; text-fig. 4, figs. 2–4, 7–12, 15–16, 19–22.

If *Orbulina suturalis* is distinguished from *O. universa* by means of the criteria described by Bronnimann (1951, p. 135), the majority of Gulf Coast Tertiary specimens will be identified as *O. suturalis*. In nearly all specimens extracted from Tertiary cores, *Globigerina*-chambers were visible above the general surface of the test. *O. suturalis* is uncommon in Pleistocene and Recent sediments of coastal Texas and Louisiana. In the American Gulf Coast the earliest specimens are found in the *Planulina harangensis* zone (Text-fig. 1), where they are abundant.

The writer was impressed by a similarity between the sphericity of chambers in the *Globigerina*-stage of *Orbulina suturalis* and the sphericity of chambers in *Globigerinoides sacculifer*. Comparisons between the two species were relatively simple, since specimens of both species were abundant in many of the cores examined. Chamber-sphericity was found during this investigation of planktonic Foraminifera, as a whole, to be a measurable feature of phylogenetic significance along with test porosity (Hofker, 1950, pp. 16–17). The resemblance of immature orbulinas in the Gulf Coast material to *Globigerinoides sacculifer* suggests that *Orbulina* stemmed from *Globigerinoides* as concluded by Cushman and Dorsey (1940, p. 41), although Bronnimann (1951, p. 137) considers it improbable that such a specialized type as *Globigerinoides* represents the initial state of *Orbulina*.

### ORBULINA UNIVERSA d'Orbigny

*Orbulina universa* D'ORBIGNY, 1839, in De la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 2, pl. 1, fig. 1; BRONNIMANN, 1951, Cushman Found. Foram. Research Contr., vol. 2, pt. 4, p. 134, text-fig. 3, fig. 12; text-fig. 4, figs. 1, 13–14.

This universally distributed species is abundant in both Recent and Pleistocene marine sediments of the Gulf Coast. Most

of the specimens from Tertiary cores, however, have *Globigerina*-chambers above the general surface of the test, and, according to the diagnosis of Bronnimann (1951, p. 135), should be included in *O. suturalis*.

### Genus PULLENIATINA Cushman, 1927
### PULLENIATINA OBLIQUILOCULATA (Parker and Jones)

*Pullenia obliquiloculata* PARKER and JONES, 1865, Royal Soc. London Philos. Trans., vol. 155, p. 368, pl. 19, fig. 4; H. B. BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 618, pl. 84, figs. 16–20.

*Pulleniatina obliquiloculata* (Parker and Jones). CUSHMAN, 1927, Cushman Lab. Foram. Research Contr., vol. 3, p. 90; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 283, pl. 22, figs. 5–7; PHLEGER and PARKER, 1951, Geol. Soc. Amer. Mem. 46, pt. 2, p. 35, pl. 19, figs. 19, 20.

This species is common in Recent samples off the coast of Texas and Louisiana and in the lower Pleistocene of Louisiana but was seldom encountered in the Tertiary core material.

### Genus SPHAEROIDINELLA Cushman, 1927
### SPHAEROIDINELLA DEHISCENS (Parker and Jones)

*Sphaeroidina dehiscens* PARKER and JONES, 1865, Royal Soc. London Philos. Trans., vol. 155, p. 369, pl. 19, fig. 5; H. B. BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 621, pl. 84, figs. 8–11.

*Sphaeroidinella dehiscens* (Parker and Jones). CUSHMAN and JARVIS, 1930, Jour. Paleontology, vol. 4, p. 367, pl. 34, figs. 6, 7; CORYELL and RIVERO, 1940, Jour. Paleontology, vol. 14, p. 340, D. K. PALMER, 1945, Bull. Am. Paleontology, vol. 29, no. 115, p. 69; CUSHMAN and TODD, 1945, Cushman Lab. Foram. Research Special Pub. 15, p. 67, pl. 11, figs. 15, 16; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 283, pl. 21, fig. 58; PHLEGER and PARKER, 1951, Geol. Soc. Amer. Mem. 46, pt. 2, p. 35.

In coastal Louisiana this species is most abundant in the lower Pleistocene. It is rare both in the Recent sediments and in the Tertiary of the Northern Gulf Coast.

### Family GLOBOROTALIIDAE
### Genus GLOBOROTALIA Cushman, 1927
### GLOBOROTALIA CANARIENSIS (d'Orbigny) var. MINIMA Akers, n. var.
### Plate 65, figures 3A–3D

Variety differing from the typical in its smaller size. A large number (143) of specimens were identified in a small core sample, and none were seen to depart appreciably from the dimensions of the holotype, which are approximately half those of the species. The species was not present in this sample, nor was it identified in any of the higher or lower zones of the Louisiana Neogene. Height of holotype, 0.22 mm.; width, 0.20 mm.; thickness, 0.11 mm.

Holotype No. 103 from the Miocene *Cibicides carstensi* var. *opimus* zone (core 10,132–10,142 feet) of the Humble Oil and Refining Company Ellender No. 1, Section 23, Township 19 South, Range 19 East, Lirette Field, Terrebonne Parish, Louisiana, Deposited in the California Company Collection, New Orleans, Louisiana.

The number of specimens of *Globorotalia canariensis* var. *minima*, n. var., yielded by cores from the above mentioned well are listed with respect to coiling and stratigraphic position as follows:

| Benthonic Indices | Depth | Number of Specimens Sinistral | Dextral |
|---|---|---|---|
| *Textularia stapperi* | 9,592 | 1 | 0 |
| | 9,602 | 2 | 0 |
| *Bigenerina humblei* | 9,898 | 1 | 0 |
| | 9,908 | 1 | 0 |
| | 9,918 | 12 | 1 |
| | 9,923 | 10 | 0 |
| | 9,933 | 4 | 0 |
| | 9,943 | 2 | 0 |
| *Cibicides carstensi* var. *opimus* | 10,132 | 137 | 6 |
| | 10,142 | 109 | 1 |
| | 10,152 | 2 | 0 |
| | 11,227 | 1 | 0 |
| | 11,247 | 2 | 0 |
| | 11,304 | 1 | 0 |

### GLOBOROTALIA FOHSI BARISANENSIS LeRoy

*Globorotalia barisanensis* LEROY, 1939, Natuurk. Tijdschr. Nederl.-Indië, vol. 99, p. 265, pl. 1, figs. 8–10; STAINFORTH, 1948a, Jour. Paleontology, vol. 22, p. 120, pl. 26, figs. 24–26.

*Globorotalia fohsi barisanensis* LeRoy. BOLLI, 1950, Cushman Found. Foram. Research Contr., vol. 1, pts. 3 and 4, p. 88, pl. 15, figs. 5–6c.

This form is rare in the Louisiana Tertiary. Several dextral specimens were found in cores from the *Cibicides carstensi* var. *opimus* and *Planulina harangensis* zones of the Shell Michel No. 1, Section 23, Township 19 South, Range 19 East, Assumption Parish, Louisiana.

### GLOBOROTALIA FOHSI FOHSI Cushman and Ellisor

*Globorotalia fohsi* CUSHMAN and ELLISOR, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 12, pl. 2, figs. 6a-c; CUSHMAN and BERMÚDEZ, 1949, Cushman Lab. Foram. Research Contr., vol. 25, p. 30. pl. 5, figs. 14–16; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 295, pl. 22, figs. 18–20.

*Globorotalia barisanensis* LeRoy. CUSHMAN and STAINFORTH, 1945, Cushman Lab. Foram. Research Special Pub. 14, p. 70, pl. 13, figs. 15a-c.

*Globorotalia fohsi fohsi*. Cushman and Ellisor. BOLLI, 1950, Cushman Found. Foram. Research Contr., vol. 1, pts. 3 and 4, p. 88, pl. 15, figs. 4a-c.

Core samples show that *Globorotalia fohsi fohsi* in Louisiana first appeared in the *Planulina harangensis* zone and became extinct at the end of *Bigenerina humblei* time (Text-fig. 1). Typical specimens are abundant in ditch samples and cores from these zones in Louisiana. Abundant specimens have been found by the writer in ditch samples from Cameron County, Texas, in association with *Bigenerina humblei*.

### GLOBOROTALIA FOHSI LOBATA Bermúdez

*Globorotalia lobata* BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 286, pl. 22, figs. 9–11.

*Globorotalia fohsi* Cushman and Ellisor. CUSHMAN and STAINFORTH, 1945, Cushman Lab. Foram. Research Special Pub. 14, p. 70, pl. 13, figs. 13a–c.

*Globorotalia fohsi lobata* Bermúdez. BOLLI, 1950. Cushman Found. Foram. Research Contr., vol. 1, pts. 3 and 4, pp. 88–89, pl. 15, figs. 7–8c.

*Globorotalia fohsi lobata* has not been identified in the Louisiana Tertiary, but several typical specimens were found by the writer in ditch samples from the marine Neogene of Cameron County, Texas.

### GLOBOROTALIA MAYERI Cushman and Ellisor

*Globorotalia mayeri* CUSHMAN and ELLISOR, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 11, pl. 2, fig. 4; ELLISOR, 1940, Am. Assoc. Petroleum Geologists Bull., vol. 24, p. 440 (list), pl. 2, fig. 9; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, p. 286, pl. 22, figs. 24–26; BRONNIMANN, 1951, Cushman Found. Foram. Research Contr., vol. 2, pt. 4, p. 131 (text-fig. 1).

*Globorotalia* cf. *G. mayeri* Cushman and Ellisor. D. K. PALMER, 1941, Soc. cubana hist. nat. Mem., vol. 15, p. 292, pl. 28, fig. 5.

The core samples examined in this study show that the species is abundant in the Louisiana Tertiary and that its range is from *Heterostegina* time to the end of *Textularia stapperi* time (Text-fig. 1). It is also abundant in ditch samples from Cameron County, Texas, but the exact limits of its range there cannot be fixed due to the lack of cored material.

### GLOBOROTALIA MENARDII (d'Orbigny)

*Rotalia menardii* D'ORBIGNY, 1826, Ann. Sci. Nat. vol. 7, p. 273; Modèles no. 10.

*Pulvinulina menardii* (d'Orbigny). H. B. BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 690, pl. 103, figs. 1, 2.

*Globorotalia menardii* (d'Orbigny). CUSHMAN, 1931, U. S. Nat. Mus. Bull. 104, pt. 8, pp. 91–94, pl. 17, fig. 1; HADLEY, 1934, Bull. Am. Paleontology, vol. 20, no. 70A, p. 25, pl. 3, figs. 12, 13; CORYELL and RIVERO, 1940, Jour. Paleontology, vol. 14, p. 336, pl. 42, figs. 34, 35; D. K. PALMER, 1941, Soc. cubana hist. nat. Mem., vol. 15, p. 291; 1945, Bull. Am. Paleontology, vol. 29, no. 115, p. 70; BERMÚDEZ, 1949, Cushman Lab. Foram. Research Special Pub. 25, pp. 286–287, pl. 22, figs. 9–11.

Gulf Coast specimens have the lower limit of their range in the *Planulina harangensis* zone of Louisiana. The Tertiary forms are much smaller than their descendents in Recent and Pleistocene sediments but appear typical in all other respects. The species has also been found in ditch samples from the Tertiary of Cameron County, Texas. *Globorotalia menardii* is abundant in Recent sediments off the coast of Louisiana and Texas and in the lower Pleistocene of Louisiana.

### GLOBOROTALIA PUNCTICULATA (d'Orbigny)

*Globigerina puncticulata* D'ORBIGNY, 1832, in Deshayes, 1832, Encyclopédie méthodique, Histoire naturalle des vers, vol. 2, pt. 2, p. 170.

*Globigerina punctulata* d'Orbigny. FORNASINI, 1898, Paleontologia Italica, vol. 4, p. 210, tf. 5.

*Pulvinulina crassa* (d'Orbigny). H. B. BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 694, pl. 103, figs. 11–12.

*Pulvinulina punctulata* (d'Orbigny). FLINT, 1899, U. S. Nat. Mus. Ann. Rept. (1897), pt. 1, p. 328, pl. 73, fig. 1.

*Globorotalia punctulata* (d'Orbigny). PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 36, pl. 20, figs. 3–7.

*Globorotalia puncticulata* (d'Orbigny). KANE, 1953, Micropaleontologist, vol. 7, no. 3, p. 30, pl. 1, fig. 9.

This species was found in Recent sediments off the coast of Louisiana and in the

marine clays of the lower Pleistocene of Louisiana. No specimens were identified in the Tertiary core samples.

GLOBOROTALIA TUMIDA (H. B. Brady)

*Pulvinulina menardii* (d'Orbigny) var. *tumida* H. B. BRADY, 1877, Geol. Mag. dec. 2, vol. 4, p. 535.
*Pulvinulina tumida* H. B. BRADY, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 692, pl. 103, figs. 4–6; FLINT, 1899, U. S. Nat. Mus. Ann. Rept. (1897), pt. 1, p. 329, pl. 73, fig. 5.
*Globorotalia tumida* (H. B. Brady). PHLEGER and PARKER 1951, Geol. Soc. America Mem. 46, pt. 2, pp. 36–37, pl. 20, figs. 14, 15.

*Globorotalia tumida* is abundant in Recent sediments off the coast of Louisiana where it is associated with *Globorotalia menardii* and other planktonic species. As in the case of all the other planktonic Foraminifera off Louisiana, however, specimens are not found in abundance except in waters of approximately 100 feet in depth and greater. No Pleistocene or Tertiary specimens were identified in the core material.

Genus GLOBOQUADRINA Finlay, 1947
GLOBOQUADRINA LARMEUI Akers, n. sp.
Plate 65, figures 4A–4C

Test small, dorsally flattened and showing all chambers; ventrally inflated, umbilicate, showing only three of the four chambers which constitute the final coil. Apertural face of last chamber not so inflated as other surface of chamber, flattened, slanting strongly inwards to umbilicus; wall finely perforate; aperture a short narrow opening at the base of the last chamber covered by a small thin labrum which projects inwards and downwards. Height of holotype, 0.34 mm.; width, 0.27 mm.; thickness, 0.20 mm.

Holotype No. 105 from the Miocene *Operculinoides* zone (core 9110–9112 feet) of Shell Godchaux Sugars No. 1, Section 97, Township 11 South, Range 7 East, St. John the Baptist Parish, Louisiana. Deposited in the California Company Collection, New Orleans, Louisiana.

This species is more similar than other described species of *Globoquadrina* to members of the genus *Globigerina* because of its higher, more inflated last chamber. The nature of the aperture is typically globoquadrine, however. *G. larmeui*, n. sp., differs from *G. obesa*, n. sp., in having a smaller final chamber which is not depressed.

The species is named for Mr. E. J. Larmeu of the California Company.

GLOBOQUADRINA OBESA Akers, n. sp.
Plate 65, figures 5A–5C

Test stout, unequally biconvex; dorsal side moderately convex, ventral side very strongly so; umbilicate; two whorls usually visible; last whorl composed of four chambers which are inflated and increase rapidly in size as added; ventral portion of last chamber flattened, often slightly concave; wall coarsely perforate; aperture a narrow opening at the base of the last chamber covered by a single small labrum. Height of holotype, 0.35 mm.; width, 0.30 mm.; thickness, 0.29 mm.

Holotype No. 104 from the Miocene *Miogypsina* zone (core 10,461–10,464 feet) of Shell Godchaux Sugars No. 1, Section 97, Township 11 South, Range 7 East, St. John the Baptist Parish, Louisiana. Deposited in the California Company Collection, New Orleans, Louisiana.

This species is similar to *Globoquadrina quadraria* (Cushman and Ellisor) var. *advena* Bermúdez from which it differs in being less convex dorsally, in having a more inflated final chamber, in having a shorter aperture, and in the consistently smaller size of the test.

GLOBOQUADRINA QUADRARIA (Cushman and Ellisor)

*Globorotalia quadraria* CUSHMAN and ELLISOR, 1939, Cushman Lab. Foram. Research Contr., vol. 15, pt. 1, p. 11, pl. 2, fig. 5.
*Globoquadrina quadraria* (Cushman and Ellisor). FINLAY, 1947, New Zealand Jour. Sci. Technology, sec. B, vol. 28, no. 5, p. 290.

Originally described from a coastal Louisiana Tertiary core as a species of *Globorotalia*, this foraminifer is considered by Finlay (1947, p. 290) to belong to a distinct and well distributed group, his genus *Globoquadrina*, of which he observes, "Most Miocene off-shore faunas seem to contain a representative, and it is possible that typical forms may be limited to upper Oligocene and Miocene." In Louisiana, the range of this species is from the *Amphistegina* zone to the *Textularia stapperi* zone (Text-fig. 1). Its coiling throughout this range is shown in Text-fig. 3. A variety of the species, *Globoquadrina quadraria* var. *advena*, has been

described by Bermúdez (1949, p. 287) from the Gurabo formation of the Dominican Republic, where it is abundant at some localities.

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ADDENDUM

Since Paul Bronnimann's observation that only weak evidence supports an upper Oligocene age for the *Globorotalia fohsi* zone of Trinidad (Micropaleontologist, vol. 6, no. 1, p. 30), H. G. Kugler has placed the base of the Caribbean Miocene at the base of the *Globorotalia fohsi* zone (Jurassic to Recent sedimentary environments in Trinidad: Bull. Ver. Schweizer. Petrol.-Geol. u. Ing., vol. 20, no. 59, 1953, pp. 27–60; The Miocene-Oligocene boundary in the Caribbean region: Geol. Mag., vol. 91, no. 5, 1954, pp. 410–414).

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 4, PP. 665–693, PLS. 66, 67, 7 TEXT-FIGS., JULY 1955

# THE FORAMINIFERAL FAUNA OF THE LATE PALAEOGENE SEDIMENTS OF THE ISLE OF WIGHT, ENGLAND*

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ABSTRACT—The little known foraminiferal fauna of the marine Oligocene beds of the Isle of Wight, England, is described. Over 100 samples from five different sections of the marine beds of the Headon, Bembridge, and Hamstead series were collected. These have yielded a foraminiferal fauna of 62 species and varieties, including three new species and three new varieties. The distribution and the known geological ranges of these species are noted. In view of the limited number of species found in these beds, no exact correlation can be made with equivalent horizons in Europe. However, the known stratigraphic ranges of species confirm the view that the Hamstead *Corbula* beds be assigned to the Middle Oligocene. The middle Headon and the Bembridge oyster beds contain a somewhat transitional foraminiferal fauna, including both Eocene and Oligocene species. However, these beds contain a large percentage of forms which have not been recorded from beds older than the Oligocene. On this basis, the Headon and the Bembridge series can be assigned to the Lower Oligocene.

## INTRODUCTION

THIS paper presents the first detailed account of the foraminiferal fauna of the Oligocene or the late Palaeogene sediments of the Isle of Wight, England. The question of the exact age of these beds has long been a subject of controversy. Although the age of the uppermost beds of this system, the Hamstead *Corbula* beds, is generally accepted to be Oligocene, there is no unanimous opinion regarding the age of the underlying Headon and Bembridge beds. The lack of unanimity in the writings of earlier workers is due more to the circumstances of deposition of the strata concerned, than to lack of knowledge of the contained faunas. For example, the lowermost marine beds in this section, the middle Headon beds, do not rest directly on the marine Eocene, but on the lower Headon beds, the exact age of which is controversial. Again, whereas the British beds are dominantly non-marine, those of Belgium, northern Germany, and to some extent those of France, are largely marine. The lithological associations and the contained faunas of these beds reflect a varied succession of facies ranging from fresh-water through brackish-water to typically marine. When dealing with beds of this type in which rapid facies variations are liable to occur both laterally and vertically, difficulty is always experienced in selecting the faunules valid for use in correlations. Furthermore, the evidence provided by the terrestrial vertebrate fauna and the marine fauna is to some extent contradictory. The present study was undertaken to clarify the disputed problem of the age of these sediments. Another paper dealing with palaeoecological studies based on foraminiferal evidence is in preparation and will be published later.

* From a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of Science, University of London, England.

## STRATIGRAPHY AND GENERAL DISTRIBUTION

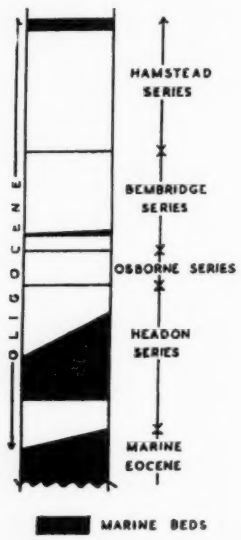
Since Thomas Webster's pioneer work of the Isle of Wight (*in* Englefield, 1816) numerous authors have studied the late Palaeogene sediments, previously called the "Fluvio-Marine" formation. Several stratigraphical classifications have been proposed, and the beds have been correlated with various portions of the European Tertiary. Most authors favor a correlation with the Oligocene, though no unanimous agreement has been reached.

The late Palaeogene sediments occupy the entire northern half of the island and are well exposed in the sections at Whitecliff Bay, Headon Hill, Totland and Colwell bays, and at Hamstead and Bouldnor cliffs.

Numerous papers have been published

relating to the stratigraphy, palaeontology, and classification of the late Palaeogene sediments of the Isle of Wight (including other parts of the Hampshire basin). Some of the important works are by d'Archaic (1839), Prestwich (1847, 1888), Dumont (1851), Lyell (1852), Forbes (1853, 1856), von Koenen (1864, 1867a, 1867b), Judd (1880, 1882), Keeping and Tawney (1881), Stamp (1921), White (1921), and Chatwin (1948).

The stratigraphic classification presented by Forbes (*op. cit.*) is eminently satisfactory and has been adopted by a large majority of later authors. These beds have been separated into four divisions, which are, in descending order (Text-fig. 1):




TEXT-FIG. 1—Generalized vertical section showing main subdivisions of the late Palaeoene sediments of the Isle of Wight. Not to scale.

4. Hamstead beds (mainly fresh-water, except marine beds at the top)
3. Bembridge beds (mainly fresh-water, except marine beds above the Bembridge limestone)
2. Osborne beds (fresh-water)
1. Headon beds (fresh-water, with marine middle Headon beds).

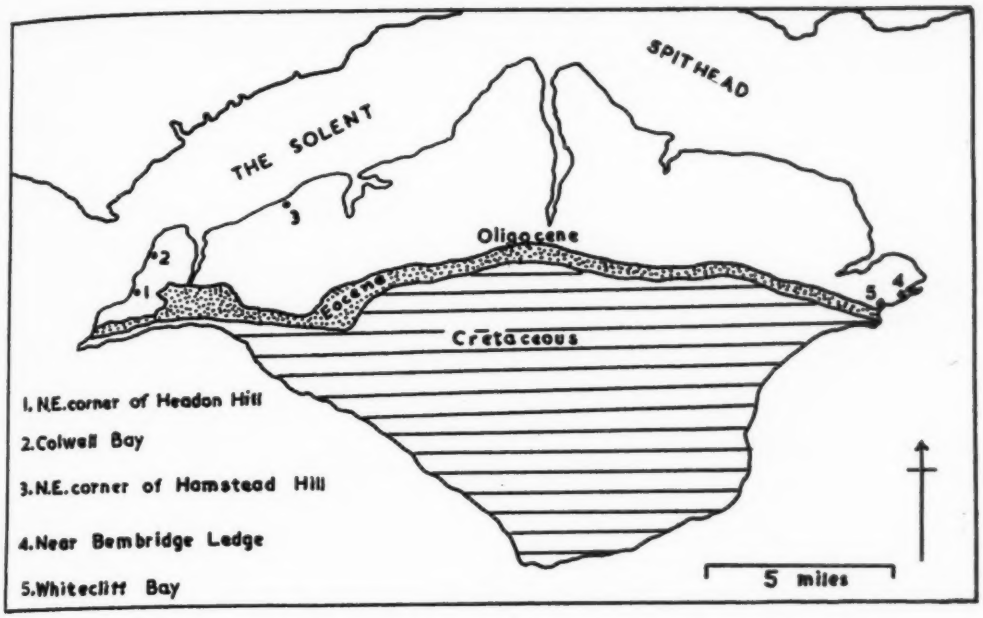
In view of the fact that a major thickness of these beds is of fresh-water and fluviatile origin, only the marine and brackish-water beds, containing a representative microfauna, will be dealt with in detail.

*Headon beds.*—The Headon beds were first described from the coastal cliff section below Headon Hill on the west coast, where they are about 147 ft. thick. From Headon Hill the beds can be traced along the coast through the sections exposed at Totland and Colwell bays as far north as Cliffend. On the east coast, however, a much better and typical section is to be observed at Whitecliff Bay, with a total thickness of about 212 ft. On the mainland, the Headon beds are exposed at Hordwell cliff, lower beds only. Also, they can be seen near Brockenhurst in the New Forest area, but there they are not so well exposed.

Three subdivisions of the Headon have been recognized. The middle Headon beds, representing the marine and brackish-water portions of the Headon strata, are well exposed at Headon Hill (33 ft.), Totland and Colwell bays (about 28–30 ft.), Whitecliff Bay (126 ft.), and on the mainland near Brockenhurst (where the exact thickness is not known). These beds have also been identified at a number of places in boreholes (*e.g.*, near Freshwater, Newport, West Cowes, etc.).

The middle Headon beds at Whitecliff Bay are more nearly typically marine than on the west coast of the island, and they contain additional strata at the base, the Brockenhurst beds. These lower beds appear to thin westward and are not represented on the west coast. The middle Headon beds in the west coast sections show an admixture of fresh-water and marine molluscs to a greater extent than at Whitecliff Bay in the east. It is therefore probable that the marine transgression which resulted in the deposition of these beds came from the east or northeast. This belief is further justified by the fact that the middle Headon beds attain a greater thickness in the east (Whitecliff Bay area) but gradually thin out westward (Colwell Bay and Headon Hill areas).

Among the important megafossils found in these beds are *Cordiopsis incrassata* (J. Sowerby), *Nucula headonensis* (Forbes), *Batillaria concava* (J. Sowerby), *Melanopsis fusiformis* (J. Sowerby), and *Theodoxus concavus* (J. Sowerby). A few corals, e.g., *Solenastraea* sp. and *Lobopsammia* sp., are




TEXT-FIG. 2—The Isle of Wight showing the three main geological divisions and location of described sections.

found in the basal Brockenhurst beds of the Whitecliff Bay and New Forest sections.

The section observed in the middle Headon beds at the northeast corner of Headon Hill is generally similar to that described by Keeping and Tawney (1881, p. 91). The thicknesses given below are approximate, as they vary. The following section was observed at the northeast corner of Headon Hill (Text-fig. 2, locality 1):

| | LITHOLOGY | | SAMPLE NO. |
|---|---|---|---|
| UPPER HEADON | Buff-colored sands with lenses of lignite | | |
| MIDDLE HEADON | Grayish-green clay with abundant *Theodoxus concavus* | 2′ | HH24–25 |
| | Brown crumply limestone with *Limnaea* | 6″ | HH23 |
| | Green clay | 6″ | HH22 |
| | *Limnaea* limestone | 1′–2″ | HH21 |
| | Stiff green clay with *Mytilus affinis, Ostrea,* etc. | 11′ | HH13–20 |
| | "*Venus* beds"—gray sandy clay with abundant *Cordiopsis incrassata, Nucula headonensis, Ancillaria buccinoides,* etc. | 11′ | HH6–12 |
| | Chocolate-colored sands with *Trigonocoelia deltoidea* | 3′ | HH2–5 |
| | Grayish-brown clay containing abundant *Theodoxus concavus* | 1′–6″ | HH1 |
| LOWER HEADON | *Limnaea* limestone | | |

The section of the middle Headon beds at Colwell Bay is very similar to the one at Headon Hill, with some minor differences owing to the lateral variation in the character of many beds and the thinning of the others. The fossils found in the middle Headon beds at Colwell Bay are much more abundant than those found at Headon Hill, and a more nearly marine character is indicated by the presence of large banks of oysters. The easy accessibility at Colwell

Bay may partly account for the apparently richer fauna. The best exposed and most extensive section of the middle Headon beds in Colwell Bay is to be seen at a point about midway between Colwell and Bramble Chines (Text-fig. 2, loc. 2):

| | LITHOLOGY | SAMPLE NO. |
|---|---|---|
| UPPER HEADON | Stiff green clay with fresh-water molluscs<br>Band of ironstone nodules | |
| MIDDLE HEADON | Bluish-green clay containing *Ostrea*, *Theodoxus*, *Cordiopsis*, etc., with occasional ironstone partings ..... 4′<br>Sands with lenses of lignite, generally unfossiliferous ..... 6″–8″ | C16–20 |
| | "*Venus* beds" with oyster bank, containing abundant specimens of *Cordiopsis incrassata*, *Ostrea velata*, etc. (the oyster bank thins on either side towards Colwell and Bramble Chines) ..... 18′–20′ | C5–15 |
| | Laminated blue sands and clays with lenses of ironstone nodules ..... (thickness variable) | C3–4 |
| | Grayish-blue sands with abundant *Theodoxus concavus* .. (thickness variable) | C1–2 |
| LOWER HEADON | Sands with crushed *Limnaea*<br>*Limnaea* limestone | |

The best developed section of the middle Headon beds on the island occurs at Whitecliff Bay on the east coast, where they attain a thickness of about 126 ft. The following section was observed at this locality (Text-fig. 2, loc. 5):

| | LITHOLOGY | | SAMPLE NO. |
|---|---|---|---|
| UPPER HEADON | Bluish-green clay with fresh-water molluscs | | |
| MIDDLE HEADON | "*Venus* beds" with *Cordiopsis incrassata* | Green sandy loam with few doubtful casts of marine shells ..... 12′ | W43–46 |
| | | Bluish-green sandy clay ..... 12′ | W33–42 |
| | | Stiff blue clay ..... 4′ | W28–32 |
| | "Barren" sands, coarse-grained bluish-green sands with occasional bands of ironstone nodules—generally unfossiliferous, except for some obscure casts of marine molluscs ..... 76′ | | W19–27 |
| | Brockenhurst beds | Brown sandy clay containing *Cardita*, *Cordiopsis*, *Ostrea*, *Voluta*, etc. ..... 12′ | W12–18 |
| | | Chocolate-colored clays full of marine molluscs, polyzoa and some corals ..... 2′ | W8–11 |
| LOWER HEADON | Fresh-water green clays and marls | | |

*Osborne beds.*—The Osborne beds exhibit varied lithology and are entirely of fresh-water origin. They consist of highly colored red and green marls with occasional intercalated bands of limestones and sands. Fresh-water molluscs and chara fruits are abundant and certain fish remains are characteristic of these beds.

*Bembridge beds.*—The Bembridge series may be subdivided into three stages: upper fresh-water marls, middle brackish-water and marine oyster beds, and lower fresh-water limestone. The only marine to brackish-water beds in the Bembridge strata are the oyster beds, which occur as a thin intercalation (7 ft.) between the fresh-water marls and the limestone containing *Limnaea*, *Planorbis*, etc. The oyster beds are best developed at Whitecliff Bay near Foreland Point, where the underlying limestone crops out just above sea level and forms the foreshore (Text-fig. 2, loc. 4). The following section was observed:

*Hamstead beds.*—These beds form the

| | LITHOLOGY | | SAMPLE NO. |
|---|---|---|---|
| BEMBRIDGE MARLS | Marls with fresh-water molluscs | | |
| BEMBRIDGE OYSTER BEDS | Stiff bluish clay, unfossiliferous | 6″ | B8 |
| | Dark clay with partings of ferruginous sands, fossils rare | 2′–6″ | B7 |
| | Green sandy clay with *Ostrea vectensis, Arca, Cordiopsis incrassata,* etc. | 2′ | B4–6 |
| | White sands with interstratified clay containing *Cyrena semistriata* | 2′ | B1–2 |
| BEMBRIDGE LIMESTONE | White compact marls with *Planorbis, Chara,* etc. Limestone with fresh-water molluscs | 1′–25′ | |

uppermost division of the late Palaeogene sediments and are best exposed in the type section at Hamstead Hill, about midway between Newtown and Yarmouth (Text-fig. 2, loc. 3). Except for the uppermost 20 ft., the *Corbula* beds, the Hamstead is mostly of fresh-water origin. The Hamstead *Corbula* beds represent the third and the last important marine phase of the late Palaeogene sedimentation.

The following section was observed in the northeast corner of Hamstead Hill:

| | LITHOLOGY | | SAMPLE NO. |
|---|---|---|---|
| SUBRECENT PLATEAU GRAVEL | | | |
| HAMSTEAD *CORBULA* BEDS | Greenish-blue clay (weathering yellow) with lenticular bands of ironstone nodules, *Ostrea callifera,* and *Volutospina rathieri* | 5′–11′ | HA10–12 |
| | Yellowish-brown shelly band with fragments of *Cyrena, Volutospina,* etc. | 4″–1′ | HA9 |
| | Stiff bluish-black clay with abundant *Corbula subpisum* and *Terebralia plicata; Corbula vectensis* is restricted to the lowermost six inches | 8′–10′ | HA1–8 |
| FRESH-WATER HAMSTEAD BEDS | Bluish clay with fresh-water molluscs | | |

## PREVIOUS WORK ON THE FORAMINIFERA OF THE LATE PALAEOGENE SEDIMENTS

The small number of references mentioned below make it clear that very little work has been done on the foraminiferal fauna of the late Palaeogene sediments of the Isle of Wight. This may be partly due to the fact that a great thickness of the sediments is of fresh-water or brackish-water origin. The marine beds, also, are not very productive.

The earliest reference to foraminifers from the Oligocene beds is by T. R. Jones (1882). The only foraminifers mentioned (in the Edwards collection) are *Quinqueloculina hauerina* d'Orbigny from the Hamstead beds and some rolled specimens of *Alveolina* from the "Fluvio-Marine" Headon beds. There are also said to be some chara fruits and marine Ostracoda in the Headon beds. Chapman (1902, p. 274) wrote that "In this country the Oligocene is not so productive, since the beds are for the main part of fresh-water or fluvio-marine character. From the Isle of Wight a small series, chiefly represented by *Miliolina* and *Polymorphina* has been obtained by the writer." Jackson (1925, p. 343) mentions *Quinqueloculina hauerina* from the Brockenhurst beds, as being in the Sandown Museum, Isle of Wight.

## LOCALITIES AND COLLECTION OF SAMPLES

The material for the present study was collected mainly from the three marine beds in the late Palaeogene sediments: the middle Headon marine beds (including the Brockenhurst beds), the Bembridge oyster beds, and the Hamstead *Corbula* beds. Although there are numerous other thin marine bands in the rest of the formation, they are not persistent.

Over a hundred samples were collected and the foraminiferal content examined. The localities listed below are indicated on the map (Text-fig. 2). Each sample represents a stratigraphic thickness of about 3–4 inches.

*Locality* 1. *Northeast corner of Headon Hill.*—25 samples (HH1–HH25) were collected from the middle Headon beds, at an average vertical interval of 1½ ft.

*Locality* 2. *Colwell Bay.*—20 samples (C1–C20) were collected from the middle Headon beds, at an average vertical interval of 1½ ft.

*Locality* 3. *Hamstead Hill.*—12 samples (HA1–HA12) were collected from the uppermost marine Hamstead *Corbula* beds—3 from the uppermost bed of greenish-yellow clay with *Ostrea callifera;* 1 from the 6″ band with broken *Cyrena semistriata;* and the remainder from the bluish-black clay with *Corbula subpisum.*

*Locality* 4. *Near Bembridge Ledge* (*Whitecliff Bay*).—8 samples (B1–B8) were collected from the Bembridge oyster beds at an average vertical interval of 10″. No samples were collected from the 3 ft. thick white marls overlying the compact Bembridge limestone, as they contain only fresh-water shells.

*Locality* 5. *Whitecliff Bay.*—A total of 39 samples (W8–W46) were collected from the middle Headon beds (including the Brockenhurst beds). Since the deposits are almost vertical at this locality, the samples were spaced out horizontally along the seashore, about 4 ft. above high tide level. Of the 39 samples, 11 were collected from the lowest Brockenhurst beds, 9 from the "Baren sands" (76 ft. thick and unfossiliferous), and the rest from the overlying "*Venus* beds."

## CLASSIFICATION AND SYSTEMATIC STUDY

In this work, Cushman's system of classification (1948) has been followed. It is the most widely accepted classification, and therefore facilitates comparison with the works of other authors.

Over 60 species and varieties were found in the marine beds of the late Palaeogene sediments. Though the fauna is limited in the number of species, the number of individuals of some species is fairly large. The following species and varieties are described as new:

*Nonion laeve* (d'Orbigny) var. *subexcavatum*
*Buliminella carteri*
*Bulimina simplex* Cushman and Parker var. *colwellensis*
*Discorbis bembridgensis*
*Pararotalia subinermis*
*Pseudoparrella oveyi*

All the holotype and paratype specimens have been deposited in the palaeontological collections at the British Museum (Natural History), London, under the registered numbers P41640–P41645.

The synonymies are arranged chronologically, and only the references to the first changes in generic names are included. All the subsequent references under a particular combination have been omitted, unless they are especially important. In cases where complete and satisfactory synonymies have already appeared, these references are cited, followed by *et syn.*, in order to avoid unnecessary repetition.

The following are explanations for the terms used in describing the distribution of species in the systematic study:

Rare = 1–5 specimens
Frequent = 6–15 specimens
Common = 16–30 specimens
Abundant = over 30 specimens

## SYSTEMATIC PALEONTOLOGY

### Order FORAMINIFERA

### Family LITUOLIDAE

### Subfamily HAPLOPHRAGMIINAE

### Genus AMMOBACULITES Cushman, 1910

### AMMOBACULITES AGGLUTINANS (d'Orbigny)

Plate 66, figure 7

*Spirolina agglutinans* D'ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 137, pl. 7, figs. 10–12.

*Haplophragmium agglutinans* (d'Orbigny) BRADY, 1884, Rept. Voy. *Challenger*, Zoology, vol. 9, p. 301, pl. 32, figs. 19–26.

*Ammobaculites agglutinans* (d'Orbigny) CUSHMAN, 1910, U. S. Nat. Mus. Bull. 71, pt. 1, p. 115, fig. 176 (*et syn.*).

*Haplophragmium agglutinans* (d'Orbigny) MARKS, 1951, Contr. Cush. Found. Foram. Res., vol. 2, pt. 2, p. 35.

*Distribution.*—Specimens occur in a very fragmentary state, the coiled planispiral portion being usually preserved. The species is very abundant in the two basal samples (HA1, HA2) and rare in sample HA5, from the Hamstead *Corbula* beds, Hamstead Hill.

*Range.*—Eocene to Recent. It is doubtful whether the various Mesozoic records by Khan (1950), from the Gault of Kent, and other authors are correct. According to Dr. T. Barnard, University College, London (personal communication), the Jurassic forms recorded as *A. agglutinans* are quite different from the Miocene species, and should be assigned to *A. fontinensis* (Terquem). This may be true of other Mesozoic records also.

Family VALVULINIDAE
Subfamily VALVULININAE
Genus CLAVULINA d'Orbigny, 1826
CLAVULINA ANGULARIS d'Orbigny
Plate 66, figure 8

*Clavulina angularis* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 268, No. 2, pl. 12, fig. 7; CUSHMAN, 1937, Cush. Lab. Foram. Res., Spec. Pub. 8, p. 19, pl. 2, figs. 29–33 (*et syn.*).

*Distribution.*—This species is apparently rare, and only single specimens were found in samples W8 and W16, from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Oligocene to Recent. Heron-Allen and Earland (Halkyard, 1918) report it from the Eocene marls of Biarritz, France, but it is doubtful if this form is the same as d'Orbigny's species.

Family MILIOLIDAE
Genus MILIOLINELLA Wiesner, 1931
MILIOLINELLA OBLONGA (Montagu)
Plate 67, figures 17a, b

*Vermiculum oblongum* MONTAGU, 1803, Test. Brit., p. 522, pl. 14, fig. 9.
*Triloculina oblonga* (Montagu) D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 300, No. 16, Modèles No. 95.
*Miliolina oblonga* (Montagu) TERRIGI, 1880, Atti Accad. Pont. Nuovi Lincei, vol. 33, p. 51, pl. 1, fig. 2.
*Triloculina oblonga* (Montagu) CUSHMAN, 1921 (1922), Contr. Canad. Biol., p. 15.
*Miliolinella oblonga* (Montagu) CUSHMAN, 1940, Foraminifera, their classification and economic use, p. 163, pl. 15, figs. 6a–c.

*Distribution.*—The species is rare in a few samples from the middle Headon beds of Headon Hill (HH11, HH18) and Colwell Bay (C1, C2), but fairly common in sample W15, from the Whitecliff Bay section. It is rare to common in all samples from the Bembridge oyster beds, and is irregularly distributed in the Hamstead *Corbula* beds. Figured specimens are from sample W15, Whitecliff Bay.

*Range.*—Eocene to Recent.

*Remarks.*—Brady's *Challenger* specimens (1884) of *Miliolina oblonga* were examined at the British Museum (Natural History), but these are not typical of the species. The test is very elongate and the tooth is small and bifid. They probably represent a different species.

In the Isle of Wight Oligocene material, the tooth is almost invariably broken or imperfectly developed. The stouter varieties approach *M. subrotunda* (Montagu). It is doubtful if the genus named *Triloculinella* Riccio (1950) is valid, as there is no real boundary between the triloculine and quinqueloculine forms.

Genus QUINQUELOCULINA d Orbigny, 1826
QUINQUELOCULINA BICARINATA d'Orbigny
Plate 67, figures 12a–c

*Quinqueloculina bicarinata* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 302, No. 35; CUSHMAN, 1945, Cush. Lab. Foram. Res., Spec. Publ. 13, p. 16, pl. 2, fig. 9; pl. 4, fig. 2 (*et syn.*).

*Distribution.*—A few specimens referable to this species were found in sample W15 from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Oligocene and Pliocene to Recent.

QUINQUELOCULINA IMPRESSA Reuss var. COGNATA (Bornemann)
Plate 67, figures 10a–c

*Quinqueloculina cognata* BORNEMANN, 1855, Deutsch. Geol. Ges., Zeitschr., vol. 7, No. 2, p. 350, pl. 9, figs. 7a–c.
*Quinqueloculina impressa* Reuss var. *cognata* (Bornemann) HAGN and HOLZL, 1952, Geologica Bavarica, Bayer. Geol. Landesamt. No. 10. p. 87.

*Distribution.*—The species is restricted to the Brockenhurst beds, Whitecliff Bay, where it is rare to frequent in three samples (W15, W32, W33).

*Range.*—Middle and Upper Oligocene.

*Remarks.*—The Isle of Wight specimens are identical with topotype specimens from the Middle Oligocene of Hermsdorf, Germany, kindly loaned by Dr. Hagn, of the university at Munich, Germany.

The variety is closely related to the typical species, and no evidence of dimorphism was noted. The specimens are apparently all megalospheric.

### QUINQUELOCULINA JULEANA d'Orbigny

Plate 67, figures 9a–c; Text-figures 3a–d

*Quinqueloculina juleana* D'ORBIGNY, 1846, Foram Foss. Bassin Tert. Vienne, p. 298, pl. 20, figs. 1–3.

?*Quinqueloculina contorta* D'ORBIGNY, 1846, *ibid.* p. 298, pl. 20, figs. 4–6.

*Quinqueloculina mariae* D'ORBIGNY, 1846, *ibid.*, p. 300, pl. 20, figs. 13–15.

*Quinqueloculina rugosa* d'Orbigny MARKS, 1951, Contr. Cush. Found. Foram. Res., vol. 2, pt. 2, p. 39, *partim* (*non* d'Orbigny, 1826; Fornasini, 1905; Cushman, 1945).

The species shows considerable variation, especially in the peripheral keels and the length of the necks (Text-fig. 3a–d). In the young forms, the peripheral margins are less acute and slightly concave. With growth, however, the margins become more acute, and in the adult specimens there are two distinct keels, with concave sides. All intermediate forms between the young and adult stages were observed. Occasionally in some specimens (Text-fig. 3d), one peripheral keel is not well developed. Thin sec-

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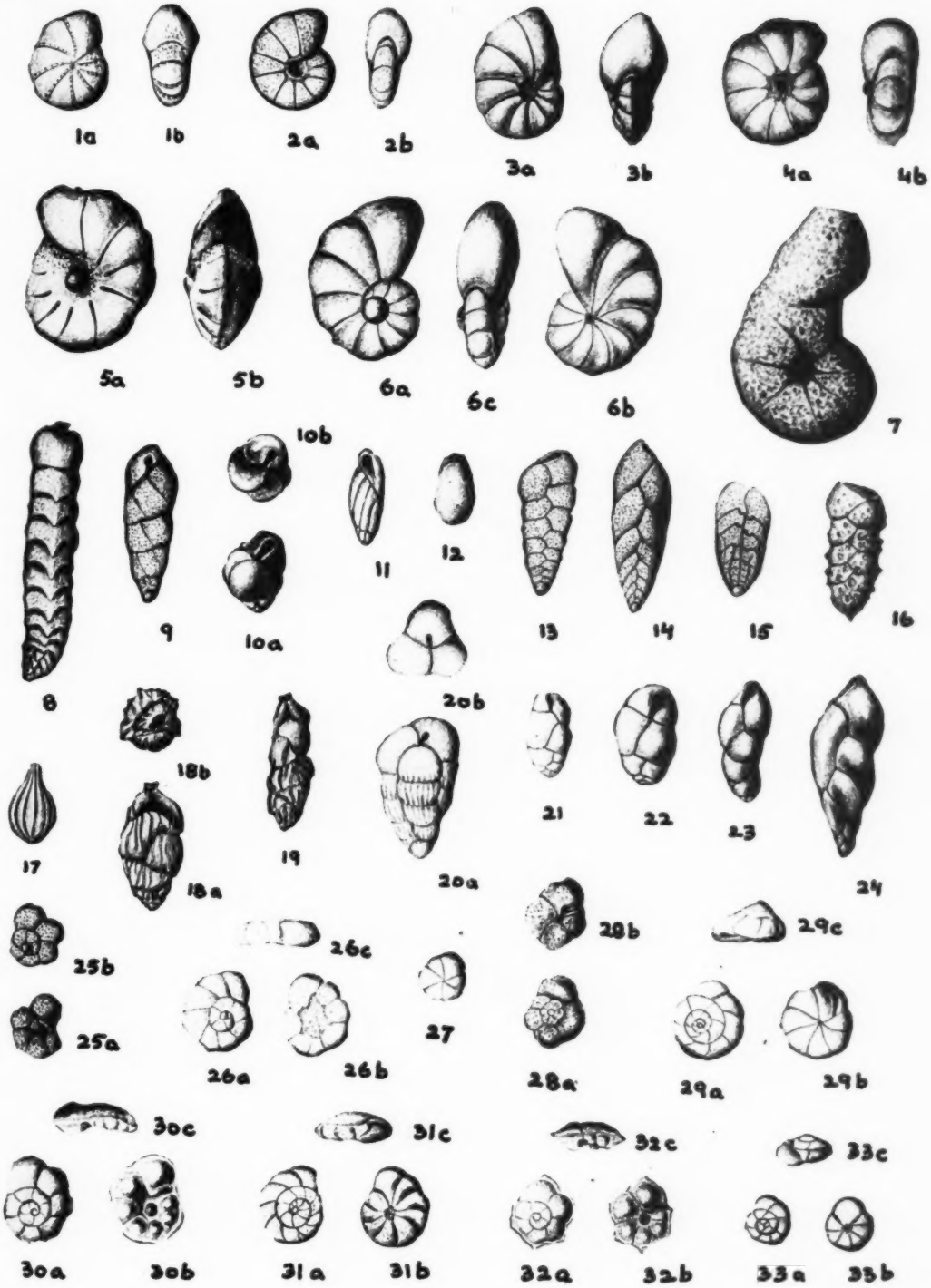
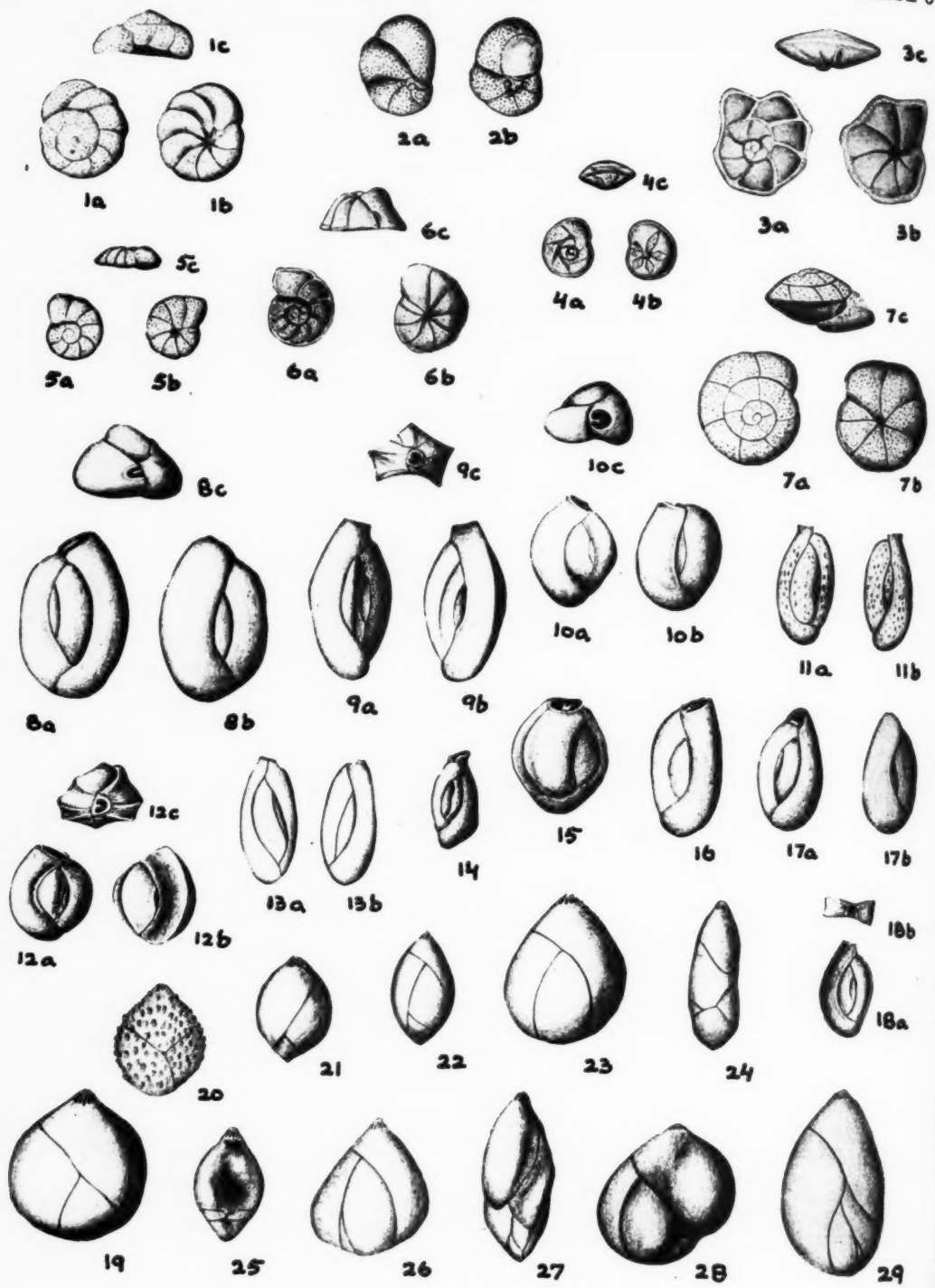
EXPLANATION OF PLATE 66

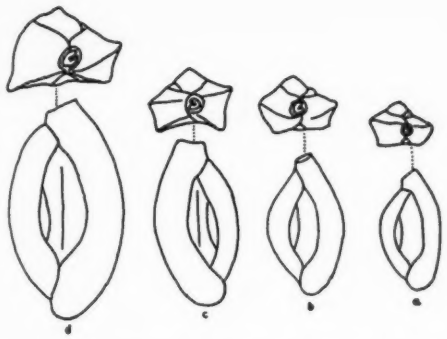
FIGS. *1*—*Elphidium minutum* (Reuss), ×50. *a*, side view; *b*, apertural view. (p. 677)
*2*—*Nonion umbilicatulum* (Walker and Jacob), ×58. *a*, side view; *b*, apertural view. (p. 678)
*3*—*Nonion scaphum* (Fichtel and Moll), ×58. *a*, side view; *b*, apertural view. (p. 677)
*4*—*Nonion depressulum* (Walker and Jacob), ×58. *a*, side view; *b*, apertural view. (p. 677)
*5*—*Nonion laeve* (d'Orbigny) var. *subexcavatum* Bhatia, n. var. Holotype, ×58. *a*, side view; *b*, apertural view. (p. 678)
*6*—*Nonionella auricula* Heron-Allen and Earland, ×90. *a*, dorsal view; *b*, ventral view; *c*, apertural view. (p. 678)
*7*—*Ammobaculites agglutinans* (d'Orbigny), ×44. (p. 670)
*8*—*Clavulina angularis* d'Orbigny, ×22. p. 671)
*9*—*Buliminella striatopunctata* (Terquem), ×57. (p. 679)
*10*—*Buliminella carteri* Bhatia, n. sp. Holotype, ×58. *a*, side view; *b*, apertural view. (p. 678)
*11*—*Buliminella elegantissima* (d'Orbigny), ×55. (p. 679)
*12*—*Entosolenia laevigata* (Reuss), ×67. (p. 680)
*13*—*Bolivina variabilis* (Williamson), ×56. (p. 681)
*14*—*Bolivina beyrichi* Reuss var. *bituminosa* Spandel, ×56. (p. 681)
*15*—*Bolivina fastigia* Cushman, ×56. (p. 681)
*16*—*Bitubulogenerina reticulata* Cushman, ×57. (p. 680)
*17*—*Lagena sulcata* (Walker and Jacob), ×35. (p. 675)
*18*—*Angulogerina tenuistriata* (Reuss), ×57. *a*, side view; *b*, apertural view. (p. 682)
*19*—*Angulogerina* aff. *A. oligocaenica* (Andreae) var. *globosa* (Stoltz), ×57. (p. 682)
*20*—*Bulimina simplex* Cushman and Parker var. *colwellensis* Bhatia, n. var. Holotype, ×90. *a*, side view; *b*, apertural view. (p. 680)
*21*—*Bulimina pupoides* d'Orbigny, ×30. (p. 680)
*22*—*Bulimina coprolithoides* Andreae, ×56. (p. 679)
*23*—*Bulimina elongata* d'Orbigny, ×56. (p. 680)
*24*—*Virgulina schreibersiana* Czjzek, ×55. (p. 681)
*25*—*Discorbis* cf. *D. rugosa* (d'Orbigny), ×40. *a*, ventral view; *b*, dorsal view. (p. 683)
*26*—*Discorbis bembridgensis* Bhatia, n. sp. Holotype, ×48. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 682)
*27*—*Pullenia* sp. indet., ×25. (p. 685)
*28*—*Globigerina* sp. indet., ×58. *a*, dorsal view; *b*, ventral view. (p. 685)
*29*—*Pseudoparrella oveyi* Bhatia, n. sp. Holotype, ×61. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 684)
*30*—*Rotalia viennensis* (d'Orbigny), ×25. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 684)
*31*—*Rotalia* aff. *R. papillosa* d'Orbigny, ×40. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 684)
*32*—*Rotalia canui* Cushman, ×40. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 684)
*33*—*Rotalia* sp. indet., ×36. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 684)




Bhatia, English Paleogene Foraminifera




Bhatia, English Paleogene Foraminifera



TEXT-FIG. 3—*Quinqueloculina juleana* d'Orbigny, from the Brockenhurst beds, Whitecliff Bay, showing the range of variation; ×35.

tions of these two contrasted types do not show any evidence of dimorphism.

*Distribution.*—Abundant in Sample W12, from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Oligocene to Miocene.

*Discussion.*—Marks (*op. cit.*) lumped together a large variety of forms under *Quinqueloculina rugosa* d'Orbigny, 1826, some of which are definitely not synonymous. *Q. rugosa*, from the Pliocene of Castel Arquato, Italy, is a very different species from the bicarinate forms (*Q. badenensis-Q. mariae*) recorded by d'Orbigny from the Miocene of the Vienna Basin, Austria. The Pliocene species, has, as the name implies, a roughened exterior. This is also evident from the descriptions given by Fornasini (1905, p. 66) and Cushman (1945, p. 16). The Miocene species, as figured by d'Orbigny, appears to be smooth. Cushman states with reference to *Q. rugosa* (1945, p. 17), "There are numerous other records from various regions, evidently not all of the same species. Fornasini's figures are reproduced on our plate and a topotype specimen figured. The angles are not as

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EXPLANATION OF PLATE 67

FIGS. *1*—*Valvulineria araucana* (d'Orbigny), ×46. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 683)
*2*—*Valvulineria subconica* (Terquem), ×40. *a*, dorsal view; *b*, ventral view. (p. 683)
*3*—*Pararotalia subinermis* Bhatia, n. sp. Holotype, ×15. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 683)
*4*—*Asterigerina* sp. indet, ×59. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 684)
*5*—*Cibicides aknerianus* (d'Orbigny), ×30. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 685)
*6*—*Cibicides refulgens* Montfort, ×30. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 688)
*7*—*Eponides* cf. *E. pygmeus* (Hantken), ×60. *a*, dorsal view; *b*, ventral view; *c*, lateral view. (p. 683)
*8*—*Quinqueloculina seminulum* (Linné), ×18. *a*, *b*, opposite sides; *c*, apertural view. (p. 674)
*9*—*Quinqueloculina juleana* d'Orbigny, ×35. *a*, *b*, opposite sides; *c*, apertural view. (p. 672)
*10*—*Quinqueloculina impressa* Reuss var. *cognata* (Bornemann), ×24. *a*, *b*, opposite sides; *c*, apertural view. (p. 671)
*11*—*Quinqueloculina pertusa* Terquem, ×26. *a*, *b*, opposite sides. (p 674)
*12*—*Quinqueloculina bicarinata* d'Orbigny, ×52 *a*, *b*, opposite sides; *c*, apertural view (p. 671)
*13*—*Quinqueloculina simplex* Terquem, ×55. *a*, *b*, opposite sides. (p. 674)
*14*—*Quinqueloculina* sp. indet., ×25. (p. 675)
*15*—*Triloculina trigonula* (Lamarck), ×48. (p. 675)
*16*—*Triloculina* cf. *T. consorbina* d'Orbigny, ×43. (p. 675)
*17*—*Miliolinella oblonga* (Montagu), ×57. *a*, *b*, opposite sides. (p. 671)
*18*—*Spiroloculina obscura* Cushman and Todd, ×30. *a*, side view; *b*, apertural view. (p. 675)
*19*—*Globulina gibba* d'Orbigny, ×48. (p. 676)
*20*—*Globulina gibba* d'Orbigny var. *tuberculata* (d'Orbigny), ×58. (p. 676)
*21*—*Globulina ampulla* (Jones), ×60. (p. 675)
*22*—*Globulina* cf. *G. minuta* (Roemer), ×58. (p. 676)
*23*—*Globulina inaequalis* Reuss, ×58. (p. 676)
*24*—*Pyrulina* sp. indet., ×57. (p. 677)
*25*—*Glandulina laevigata* d'Orbigny, ×58. (p. 675)
*26*—*Guttulina irregularis* (d'Orbigny), ×48. (p. 676)
*27*—*Guttulina austriaca* d'Orbigny, ×46. (p. 676)
*28*—*Guttulina bulloides* (Reuss), ×46. (p. 676)
*29*—*Sigmomorphina* sp. indet., ×90. (p. 677)

definitely ridged as in Fornasini's figures but it has been shown many times that these tracings are not accurate in all details. The surface is slightly roughened." Cushman's figures of a topotype specimen (*op. cit.*, pl. 2, figs. 15a, b) show a fairly large species, without any definite neck, and with ribs over some chambers. This last character is not apparent in d'Orbigny's figures. The type specimens of the species, however, have been lost (*vide* d'Orbigny's index cards issued by the Laboratoire de Micropaléontologie, Institut Français du Pétrole, Paris).

Although topotype specimens were not available, it is apparent from Cushman's figures that *Q. rugosa* from the Pliocene is not the same as the bicarinate Miocene species (*Q. badenensis–Q. mariae*), referred to in Marks' synonymy.

Another important point which Marks seems to have overlooked, is the fact that *Q. rugosa* (1826), though the older name, was a *nomen nudum* until the species was figured by Fornasini in 1905, and therefore it cannot have priority over the Miocene species (d'Orbigny, 1846) referred to above.

*Q. badenensis* d'Orbigny (1846, p. 299, pl. 20, figs. 10–12) is a stouter form, without any neck, and it is most probably a different species. The type specimens of this species are figured in d'Orbigny's Index Cards, issued by the Laboratoire de Micropaléontologie, Institut Français du Pétrole, Paris.

*Q. rodolphina* d'Orbigny (*op cit.*, p. 299, pl. 20, figs, 7–9) has three distinct keels and is therefore omitted from the present synonymy.

*Q. contorta* d'Orbigny (*op. cit.*, p. 298, pl. 20, figs. 4–6) has no neck and the sides are almost parallel. It appears probable that *Q. contorta* (0.5 mm.) is a juvenile form of *Q. juleana* (1.0 mm.) and that the two are synonymous. The dimensions given are after d'Orbigny. Should that be the case, the former name would take precedence. However, for the present, the Isle of Wight species is called *Q. juleana*, as it appears to resemble closely d'Orbigny's figures of that species.

*Q. mariae* d'Orbigny (*op. cit.*, p. 300, pl. 20, figs. 13–15) is apparently a slight variant of *Q. juleana*, as it has only a single keel on one side. A few specimens referable to this species were found in the present material, and they come within the range of variation of *Q. juleana*.

### QUINQUELOCULINA PERTUSA Terquem
Plate 67, figures 11a, b

*Quinqueloculina pertusa* TERQUEM, 1882, Mém. Soc. Géol. France, sér. 3, vol. 2, p. 183, pl. 20, figs. 5a–c; LE CALVEZ, 1947, Serv. Carte Géol. Mém., Paris, I, p. 13, pl. 1, figs. 16–18 (*et syn.*).

*Distribution.*—Rare in sample W15, Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to lower Oligocene.

### QUINQUELOCULINA SEMINULUM (Linné)
Plate 67, figures 8a–c

*Serpula seminulum* LINNÉ, 1758, Systema Naturae, Edn. 10, p. 786.
*Quinqueloculina seminulum* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 303, No. 44.
*Miliolina seminulum* WILLIAMSON, 1858, Recent Foram. Gt. Britain, pp. 85, 86, pl. 7, figs. 183–185; BRADY, 1884, Rept. Voy. *Challenger*, Zoology, vol. 9, p. 157, figs. 6a–c.
*Quinqueloculina seminulum* CUSHMAN, 1917, U.S. Nat. Mus. Bull. 71, pt. 6, p. 44, pl. 11, fig. 2

*Distribution.*—The distribution of this species in the Oligocene sections of the Isle of Wight is irregular. In some samples the species is represented by only a few specimens; in other cases it is found to be abundant. However, it was found only in the middle Headon beds of Colwell Bay and Whitecliff Bay sections and in 3 samples (HA2, HA3, HA7) from the Hamstead *Corbula* beds, Hamstead Hill. The figured specimens are from sample W41, middle Headon beds, Whitecliff Bay.

*Range.*—Eocene to Recent.

*Remarks.*—*Q. seminulum* is a variable species, and a large number of similar forms have been described under different names. Accordingly, it is difficult to give an adequate synonymy and an exact distribution. Brady (*op. cit.*), in his synonymy has grouped together a large variety of forms, some of which are evidently very different from *Q. seminulum* (Linné).

### QUINQUELOCULINA SIMPLEX Terquem
Plate 67, figures 13a, b

*Quinqueloculina simplex* TERQUEM, 1882, Mém. Soc. Géol. France, sér. 3, vol. 2, p. 172, pl.

18, figs. 7–13; LE CALVEZ, 1947, Serv. Carte Géol. Mém., Paris, I, p. 13, pl. 1, figs. 13–15.

*Distribution.*—The species is very irregularly distributed in the middle Headon beds; it is rare to common in the Whitecliff Bay section and rare in one sample (C16) from the Colwell Bay section. It is also rare in one sample (HA3) from the Hamstead *Corbula* beds, Hamstead Hill. The figured specimens are from sample W41, middle Headon beds, Whitecliff Bay.

*Range.*—Ecoene to middle Oligocene.

*Remarks.*—The species is identical with those from the Eocene of the Paris Basin (*fide* Le Calvez, personal communication).

QUINQUELOCULINA sp. indet.
Plate 67, figure 14

This indeterminate form was found only in one sample (HA3) from the Hamstead *Corbula* beds, Hamstead Hill, in which it is frequent.

Genus SPIROLOCULINA d'Orbigny, 1826
SPIROLOCULINA OBSCURA Cushman and Todd
Plate 67, figures 18a, b

*Spiroloculina obscura* CUSHMAN and TODD, 1944, Cush. Lab Foram. Res., Spec. Publ. 11, p. 20, pl. 1, fig. 8; pl. 3, figs. 22–25 (*et syn.*).

*Distribution.*—Rare in sample W15, from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Miocene.

Genus TRILOCULINA d'Orbigny, 1826
TRILOCULINA TRIGONULA (Lamarck)
Plate 67, figure 15

*Miliolites trigonula* LAMARCK, 1804, Ann. Mus., vol. 5, p. 351, No. 3.
*Triloculina trigonula* (Lamarck) D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 229, pl. 16, figs. 5–9; MARKS, 1951, Contr. Cush. Found. Foram. Res., vol. 2, pt. 2, p. 41 (*et syn.*).

*Distribution.*—Rare to common in three samples (W12, W15, W18) from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Recent.

TRILOCULINA cf. T. CONSORBINA d'Orbigny
Plate 67, figure 16

The species may be questionably referred to *T. consorbina* d'Orbigny. It is rare to frequent in three samples (B1, B2, B4) from the Bembridge Oyster beds, Whitecliff Bay.

Family LAGENIDAE
Subfamily LAGENINAE
Genus LAGENA Walker and Jacob, 1798
LAGENA SULCATA (Walker and Jacob)
Plate 66, figure 17

*Serpula* (*Lagena*) *striata sulcata rotundata* WALKER and BOYS, 1784, Testacea minuta rariora, p. 2, pl. 1, fig. 6.
*Serpula* (*Lagena*) *sulcata* WALKER and JACOB, 1798, Adam's Essays, Kanmacher's edn., p. 634, p. 14, fig. 5.
*Lagena sulcata* (Walker and Jacob) PARKER and JONES, 1865, Philos. Trans., vol. 155, p. 351; CUSHMAN, 1913, U. S. Nat. Mus. Bull. 71, pt. 3, p. 22, pl. 9, fig. 2 (*et syn.*).

*Distribution.*—One single specimen referable to this species was found in sample HH11, from the middle Headon beds at Headon Hill.

*Range.*—Cretaceous to Recent.

Family POLYMORPHINIDAE
Subfamily POLYMORPHININAE
Genus GLANDULINA d'Orbigny, 1826
GLANDULINA LAEVIGATA d'Orbigny
Plate 67, figure 25

*Nodosaria* (*Glandulina*) *laevigata* D'ORBIGNY, 1826, Ann. Sci. Nat. vol. 7, p. 252, pl. 10, figs. 1–3.
*Glandulina laevigata* D'ORBIGNY, 1846, Foram. Foss. Bassin Tert. Vienne, p. 29, pl. 1, figs. 4–5; CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 143, pl. 40, figs. 1a, b.

*Distribution.*—Rare in sample W18, from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Recent.

Genus GLOBULINA d'Orbigny, 1839
GLOBULINA AMPULLA (JONES)
Plate 67 figure 21

*Polymorphina ampulla* JONES, 1852, Quart. Journ. Geol. Soc., vol. 8, p. 267, pl. 16, fig. 14.
*Polymorphina gibba* d'Orbigny var. *ampulla* BURROWS and HOLLAND, 1897, Proc. Geol. Assoc., vol. 15, p. 45, pl. 2, fig. 14.
*Globulina ampulla* (Jones) CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 79, pl. 19, figs. 9a–c (*et syn.*), (*non vidi Guttulina nitida* d'Orbigny, 1826; Fornasini, 1901).

*Distribution.*—One specimen referable to this species was found in sample W9, from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Lower Eocene to lower Oligocene.

*Remarks.*—The type specimens of *Polymorphina ampulla* (Jones) were examined at

the British Museum (Natural History) (Cat. No. P239). Most of the specimens mounted in the type slide have been damaged and are hardly identifiable. The figures given by Cushman and Ozawa (*loc. cit.*) therefore served as the basis for identification.

GLOBULINA GIBBA d'Orbigny
Plate 67, figure 19

*Polymorphina* (*Globulina*) *gibba* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 266, No. 10, Modèles No. 63.
*Globulina gibba* D'ORBIGNY, 1846, Foram. Foss. Bassin. Tert. Vienne, p. 227, pl. 13, figs. 13–14. CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 60, pl. 16, figs. 1–4 (*et syn.*).

*Distribution.*—Rare to frequent in four samples (W8, W12, W15, W17), from the Brockenhurst beds, Whitecliff Bay.

*Range.*—*G. gibba* is a cosmopolitan species and has been recorded from formations ranging in age from Eocene to Recent. The records from Mesozoic deposits are not correct (*fide* Cushman and Ozawa, *loc. cit.*).

GLOBULINA GIBBA d'Orbigny var. TUBERCULATA (d'Orbigny)
Plate 67, figure 20

*Globulina tuberculata* D'ORBIGNY, 1846, Foram. Foss. Bassin Tert. Vienne, p. 230, pl. 13, figs. 21, 22.
*Globulina gibba* d'Orbigny var. *tuberculata* (d'Orbigny) CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 68, pl. 17, figs. 6, 7 (*et syn.*).

*Distribution.*—Only one specimen referable to this species was found in sample W8, from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Pliocene, ?Recent.

GLOBULINA INAEQUALIS Reuss
Plate 67, figure 23

*Globulina translucida* D'ORBIGNY (*nomen nudum*), 1826, Ann. Sci. Nat., vol. 7, p. 267, no. 25.
*Globulina inaequalis* REUSS, 1850, Denkschr. K. Akad. Wiss. Wien, vol. 1, p. 377, pl. 48, fig. 9; CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 73, pl. 18, figs. 2–4 (*et syn.*).

*Distribution.*—Rare to frequent in four samples (W8, W9, W12, W15), from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Recent.

*Remarks.*—*G. translucida* d'Orbigny, 1826, although the older name, was a *nomen nudum* until figured by Terquem in 1882 and later by Fornasini in 1901, and therefore it does not have priority over Reuss' name.

The species is closely allied to *G. gibba*, but differs from it in the slightly oblong shape and the compressed test.

GLOBULINA cf. G. MINUTA (Roemer)
Plate 67, figure 22

A few specimens from the middle Headon beds at Whitecliff Bay (W8, W9, W15, W29) may be questionably referred to this species.

Genus GUTTULINA d'Orbigny, 1839
GUTTULINA AUSTRIACA d'Orbigny
Plate 67, figure 27

*Guttulina austriaca* D'ORBIGNY, 1846, Foram. Foss. Bassin Tert. Vienne, p. 223, pl. 12, figs. 23–25; CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 29, pl. 4, figs. 3–5 (*et syn.*).

*Distribution.*—Rare in sample HA7, from the Hamstead *Corbula* beds, Hamstead Hill.

*Range.*—Eocene to Recent.

GUTTULINA BULLOIDES (Reuss)
Plate 67, figure 28

*Globulina bulloides* REUSS, 1861 (1862), Sitzungsber. d. k. Akad. Wiss. Wien, vol. 44, pl. 1, p. 318, pl. 3, fig. 4.
*Guttulina bulloides* TERQUEM (?) 1878, Mém. Soc. Géol. France, sér. 3, vol. 1, p. 47, pl. 4(9), figs. 27a, b; CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 23, pl. 1, figs. 7, 8 (*et syn.*).

*Distribution.*—Rare in samples W12 and HH8, from Whitecliff Bay and Headon Hill sections respectively. The figured specimen is from sample W12.

*Range.*—Cretaceous to Miocene.

GUTTULINA IRREGULARIS (d'Orbigny)
Plate 67, figure 26

*Globulina irregularis* D'ORBIGNY, 1846, Foram. Foss. Bassin Tert. Vienne, p. 226, pl. 13, figs. 9, 10.
*Guttulina irregularis* (d'Orbigny) CUSHMAN and OZAWA, 1930, Proc. U. S. Nat. Mus., vol. 77, p. 25, pl. 3, figs. 4, 5; pl. 7, figs. 1, 2 (*et syn.*).

*Distribution.*—Rare to frequent in samples W8, W9, and W29) from the middle Headon beds, Whitecliff Bay.

*Range.*—The species, like *Globulina gibba*, has a wide geographical distribution as well

as long geological range (Cretaceous to Recent).

Genus PYRULINA d'Orbigny, 1839
PYRULINA sp. indet.
Plate 67, figure 24

The single specimen figured, and the only one found in this material, occurs in sample W28, from the middle Headon beds, Whitecliff Bay. The sutures are too obscure to be of any help in specific determination.

Genus SIGMOMORPHINA Cushman and Ozawa, 1928
SIGMOMORPHINA sp. indet.
Plate 67, figure 29

Single specimens of this indeterminate form were found in samples W9 and W12, from the Brockenhurst beds, Whitecliff Bay.

Family NONIONIDAE
Genus ELPHIDIUM Montfort, 1808
ELPHIDIUM MINUTUM (Reuss)
Plate 66, figures 1a, b

*Polystomella minuta* REUSS, 1865, Sitzungsber. D. K. Akad. Wiss. Wien, vol. 50, pt. 1, p. 478, pl. 4, figs. 6a, b.
*Elphidium minutum* (Reuss) CUSHMAN, 1939, U. S. Geol. Surv., Prof. Paper 191, p. 40, pl. 10, figs. 22–25 (*et syn.*); MARKS, 1951, Contr. Cush. Found. Foram. Res., vol. 2, pt. 2, p. 53, pl. 6, figs. 6a, b.

*Distribution.*—The species is common in the middle Headon beds of Colwell Bay and Headon Hill, where it occurs in the majority of the samples. In the Whitecliff Bay section it was found only in samples W8, W9, W12, and W31. The figured specimens are from sample HH13, Headon Hill.

*Range.*—Oligocene to Miocene.

Genus NONION Montfort, 1808
NONION SCAPHUM (Fichtel and Moll)
Plate 66, figures 3a, b

*Nautilus scapha* FICHTEL and MOLL, 1798, Test. Micr., p. 105, pl. 19, figs. d–f.
*Nonionina communis* D'ORBIGNY, 1846, Foram. Foss. Bassin Tert. Vienne, p. 106, pl. 5, figs. 7, 8 (*et auctorum*).
*Nonionina asterisans* (F. & M.) var. *scapha* (F. & M.) PARKER and JONES, 1859, Ann. Mag. Nat. Hist., ser. 3, vol. 5, p. 5.
*Nonionina scapha* (F. & M.) BRADY, 1865, Nat. Hist. Trans. Northumberland and Durham, vol. 1, p. 106, pl. 12, figs. 10a, b.
*Nonion scaphum* (F. & M.) CUSHMAN, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 5, pl. 2, figs. 3, 4; MARKS, 1951, Contr. Cush. Found. Foram. Res., vol. 2, pt. 2, p. 49, pl. 5, figs. 16a, b (*et syn.*).

*Distribution.*—Rare to frequent in two samples (HA6, HA7), from the Hamstead *Corbula* beds, Hamstead Hill.

*Range.*—Eocene to Recent.

*Remarks.*—The two species *N. scaphum* and *N. communis* are considered to be synonymous (*fide* Marks, *op. cit.*). The Isle of Wight specimens are identical with Brady's *Challenger* specimens (1884) at the British Museum (Natural History).

NONION DEPRESSULUM (Walker and Jacob)
Plate 66, figures 4a, b

*Nautilus spiralis utrinque subumbilicatus* . . . WALKER and BOYS, 1784, Testacea minuta rariora, p. 19, pl. 3, fig. 68.
*Nautilus depressulus* WALKER and JACOB, 1798, Adam's Essays, Kanmacher's edn., p. 641, pl. 14, fig. 33.
*Nonionina umbilicatula* WILLIAMSON (*non* W. & J.), 1858, Recent Foram. Gt. Britain, p. 97, pl. 3, figs. 70, 71.
*Nonionina asterisans* (F. & M.) var. *depressula* (W. & J.) PARKER and JONES, 1859, Ann. Mag. Nat. Hist., ser. 3, vol. 4, pp. 339, 341.
*Polystomella* (*Nonionina*) *crispa* (Linné) var. *depressula* (W. & J.) PARKER and JONES, 1865, Philos. Trans., vol. 155, p. 403, pl. 14, figs. 39a, b.
*Nonionina depressula* (W. & J.) BRADY, 1865, Nat. Hist. Trans. Northumberland and Durham, vol. 1, p. 106.
*Nonion depressulum* (W. & J.) CUSHMAN, 1930, U. S. Nat. Mus., Bull. 104, pt. 7, p. 3, pl. 1, figs. 3–6.

The species varies considerably in the number of chambers, curvatures of sutures, and the amount of umbilical ornamentation. The young forms have 7 or 8 chambers, gently curved sutures, and little umbilical ornamentation—the umbilical knob may be absent. The adult forms have 11–13 chambers and the sutures are distinctly curved. The periphery is broadly rounded.

*Distribution.*—The species occurs in a large majority of the samples from the Oligocene material of the Isle of Wight. It is more abundant in the shallow-water assemblages of the middle Headon and Bembridge oyster beds.

*Range.*—Eocene?, Oligocene to Recent.

*Remarks.*—The Eocene species should probably be ascribed to *N. graniferum* (Terquem), which has very large beads in the umbilicus and a wide open aperture.

NONION LAEVE (d'Orbigny) var. SUBEXCAVATUM Bhatia, n. var.
Plate 66, figures 5a, b

*Diagnosis.*—In this variety the sutures are only slightly excavated and do not extend to the umbo. In some cases, the surface is ornamented with small granules of shell material which run from the periphery to the uppermost part of the umbo.

*Dimensions.*—Diameter 0.20–0.41 mm.; thickness 0.12–0.19 mm.

*Type material.*—The holotype (Cat. No. P41642) is from sample W12, Brockenhurst beds, Whitecliff Bay. A total of 14 specimens were collected, distributed among four basal samples from the Brockenhurst beds. The diameter of the holotype is 0.41 mm. and the thickness 0.19 mm.

*Type locality.*—Locality No. 5, Whitecliff Bay, Isle of Wight. The types were from the Brockenhurst beds, chocolate-colored sandy clay. The associated faunule consists dominantly of *Cibicides aknerianus, Bitubulogenerina reticulata,* and *Quinqueloculina juleana.*

*Geologic age.*—Lower Oligocene, Lattorfian.

*Discussion.*—The variety was compared with the typical specimens of *N. laeve,* from the Eocene of Grignon, Paris basin. The two are closely allied, except that the Eocene species has very distinct and strongly depressed sutures and prominent umbones. The differences are fairly constant.

NONION UMBILICATULUM (Walker and Jacob)
Plate 66, figures 2a, b

*Nautilus spiralis umbilicatus geniculis sulcatis* WALKER and BOYS, 1784, Testacea minuta rariora, p. 19, pl. 3, fig. 69.

*Nautilus umbilicatulus* WALKER and JACOB, 1798, Adam's Essays, Kanmachers edn., p. 641, pl. 14, fig. 34.

*Nonionina affinis* REUSS, 1851, Deutsch. Geol. Ges., Zeitschr., vol. 3, p. 72, pl. 5, figs. 32a, b (*et auctorum*).

*Truncatulina lobatula* (W. & J.) var. *umbilicatula* (W. & J.) PARKER and JONES, 1859, Ann. Mag. Nat. Hist., ser. 3, vol. 4, pp. 339, 341.

*Polystomella* (*Nonionina*) *crispa* (Linné) var. *umbilicatula* PARKER and JONES, 1865, Philos. Trans., vol. 155, p. 405, pl. 14, figs. 42a, b; pl. 17, figs. 58, 59.

*Nonionina umbilicatula* (Montagu) BRADY, 1865, Nat. Hist. Trans., Northumberland and Durham, vol. 1, p. 106; 1884, Rept. Voy. *Challenger,* Zoology, vol. 9, p. 726, pl. 109, figs. 8, 9.

*Nonion umbilicatulum* (Montagu) CUSHMAN, 1928, Cush. Lab. Foram. Res., Spec. Publ. 1, p. 202, pl. 27, figs. 3a, b.

*Distribution.*—Rare to common in four samples (W8, W9, W12, W15), from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Recent.

*Remarks.*—Brady's Challenger specimens (1884) deposited in the British Museum (Natural History) are fairly typical of the species.

Topotype specimens of *N. affine* (Reuss) from the Middle Oligocene of Hermsdorf, Germany, were examined. These are identical in every respect with the present species.

Genus NONIONELLA Cushman, 1926
NONIONELLA AURICULA Heron-Allen and Earland
Plate 66, figures 6a-c

*Nonionella auricula* HERON-ALLEN and EARLAND, 1930, Jour. Roy. Micr. Soc., ser. 3, vol. 50, pt. 11, p. 192, pl. 5, figs. 68–70; CUSHMAN, 1939, U. S. Geol. Surv., Prof. Paper 191, p. 33, pl. 9, figs. 7–9; 1944, Cush. Lab. Foram. Res., Spec. Publ. 12, p. 25, pl. 3, figs. 26, 27.

*Distribution.*—The species was found only in the Hamstead *Corbula* beds, Hamstead Hill, where it is common in three samples (HA6, HA7, HA9).

*Range.*—Middle Oligocene and Recent. The species has not previously been reported in the fossil state.

*Remarks.*—The species was compared and found to be identical with the type specimens in the British Museum (Natural History).

Family BULIMINIDAE
Subfamily TURRILININAE
Genus BULIMINELLA Cushman, 1911
BULIMINELLA CARTERI Bhatia, n. sp.
Plate 66, figures 10a, b

?*Buliminella* sp. CUSHMAN and RENZ, 1947, Cush. Lab. Foram. Res., Spec. Publ. 22, p. 23, pl. 6, fig. 1.

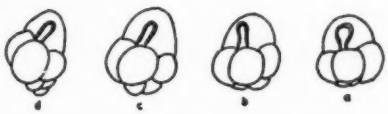
*Diagnosis.*—Test small, globose, initial end rounded; chambers distinct, somewhat inflated, 4 to 5 in the last whorl which forms more than two-thirds of the test; sutures distinct, depressed; wall smooth, finely perforate; aperture fairly large, comma-shaped, with a slight lip.

The species shows all gradations (Text-fig.

4a–d) from stout varieties with broadly rounded initial ends to slightly elongate forms with subacute initial ends.

*Dimensions.*—Length 0.11–0.20 mm.; diameter 0.09–0.19 mm.

*Type material.*—The holotype (Cat. No. P41643) (Plate 66, figures 10a, b) measures 0.20 mm. in length and 0.16 mm. in diameter; from sample HA7, Hamstead *Corbula* beds, Hamstead Hill.



TEXT-FIG. 4—*Buliminella carteri* Bhatia, n. sp., from the Hamstead *Corbula* beds, Hamstead Hill, showing variation of the species; ×58.

Besides the type horizon, the species also occurs in the Bembridge oyster beds and middle Headon beds. Over 80 specimens were collected from several samples distributed among the above-mentioned beds.

*Type locality.*—Locality No. 3, Hamstead Hill, Isle of Wight. The type specimens were from the Hamstead *Corbula* beds, forming the uppermost 20 ft. or so of the Hamstead unit. The source is 8–10 ft. of stiff bluish-black clay in which *Corbula subpisum* is abundant. The associated faunule consists dominantly of *Bulimina* spp., *Bolivina fastigia, B. variabilis, Angulogerina tenuistriata,* and *Pullenia* sp. indet.

*Geologic age.*—The type specimens are from the Middle Oligocene, Rupelian. The species also occurs in the Lower Oligocene, Lattorfian.

*Discussion.*—Cushman and Renz (*op. cit.*) figured a somewhat similar species from the Oligocene of Trinidad, British West Indies, but did not assign a name to it. The present species may be identical with the Trinidad one.

*Remarks.*—The species is named after Mr. D. J. Carter, in recognition of his help and guidance during the preparation of this work.

### BULIMINELLA ELEGANTISSIMA (d'Orbigny)
Plate 66, figure 11

*Bulimina elegantissima* D'ORBIGNY, 1839, Voyage dans l'Amérique Méridionale; Foraminifères, Strasbourg, vol. 5, pt. 5, p. 51, pl. 7, figs. 13–14.
*Buliminella elegantissima* (d'Orbigny) CUSHMAN, 1911, U. S. Nat. Mus., Bull. 71, pt. 2, p. 89; CUSHMAN and PARKER, 1947, U. S. Geol. Surv., Prof. Paper 210-D, p. 67, pl. 17, figs. 10–12 (*et syn.*).

*Distribution.*—Rare in sample HH13, from the middle Headon beds, Headon Hill. Frequent to common in the Bembridge oyster beds and Hamstead *Corbula* beds.

*Range.*—This is a cosmopolitan species and is known to range from Eocene to Recent.

### BULIMINELLA STRIATOPUNCTATA (Terquem)
Plate 66, figure 9

*Bulimina striato-punctata* TERQUEM, 1882, Mém. Soc. Géol. France, sér. 3, vol. 2, p. 116, pl. 12, fig. 19.
*Buliminella striato-punctata* (Terquem) LE CALVEZ, 1950, Serv. Carte Géol. Mém. Paris, III, p. 30, pl. 2, figs. 29, 30 (*et syn.*).

*Distribution.*—The species first appears in the basal part of the middle Headon beds of Colwell Bay, where it is rare to frequent in seven samples (C1-C7). In the basal part of the Bembridge oyster beds, it is very common, but becomes rare towards the top. The figured specimen is from the Bembridge oyster beds.

*Range.*—Eocene to Lower Oligocene. The species has previously been recorded from only the Eocene of the Paris Basin.

*Remarks.*—The Oligocene specimens were compared with topotype specimens from the Eocene of the Paris Basin, and found to be identical with them, except that the length of the test is slightly less than in those from the Paris Basin.

## Subfamily BULIMININAE
## Genus BULIMINA d'Orbigny, 1826

### BULIMINA COPROLITHOIDES Andreae
Plate 66, figure 22

*Bulimina coprolithoides* ANDREAE, 1884, Abhandl. Geol. Spec. Karte Elsass Loth., vol. 2, pt. 3, p. 306, pl. 6, figs. 4a–d; CUSHMAN and PARKER, 1947, U. S. Geol. Surv., Prof. Paper 210-D, p. 102, pl. 24, figs. 9a–c (*et syn.*).

*Distribution.*—The species is rare to frequent in the majority of the samples from the middle Headon beds of Colwell Bay and Headon Hill, and in two samples (W29, W41) from the Whitecliff Bay section. It is also rare to common in a few samples (B1, B2, B4, B5, B6) from the Bembridge oyster

beds. It is very common in the Hamstead *Corbula* beds of Hamstead Hill, where it was found to be present in almost every sample. The figured specimen is from sample HA7, Hamstead *Corbula* beds.

*Range.*—Eocene?, Oligocene.

*Remarks.*—The species is closely allied to *B. pupoides*, but can be distinguished by the characteristic position of the aperture above the junction of the second and third chamber. This difference is fairly constant.

BULIMINA ELONGATA d'Orbigny
Plate 66, figure 23

*Bulimina elongata* D'ORBIGNY, 1846 (*non* 1826), Foram. Foss. Bassin Tert. Vienne, p. 187, pl. 11, figs. 19, 20; CUSHMAN and PARKER, 1947, U. S. Geol. Surv., Prof. Paper 210-D, p. 108, pl. 25, figs. 14–17 (*et syn.*).

*Distribution.*—Frequent to common in most of the samples from the Hamstead *Corbula* beds, Hamstead Hill.

*Range.*—Eocene to Recent.

BULIMINA PUPOIDES d'Orbigny
Plate 66, figure 21

*Bulimina pupoides* D'ORBIGNY, 1846, Foram. Foss. Bassin Tert. Vienne, p. 185, pl. 11, figs. 11, 12; CUSHMAN and PARKER, 1947, U. S. Geol. Surv., Prof. Paper 210-D, p. 105, pl. 25, figs. 3–7 (*et syn.*).

*Distribution.*—Rare in sample HA7 from the Hamstead *Corbula* beds and frequent in few samples from the Bembridge oyster beds. The figured specimen is from sample HA7.

*Range.*—Eocene to Recent.

BULIMINA SIMPLEX Cushman and Parker
var. COLWELLENSIS
Bhatia, n. var.
Plate 66, figures 20a, b

*Diagnosis.*—Test minute, more than twice as long as broad, tapering towards the rounded initial end; proloculum fairly large; chambers numerous, inflated, arranged in a regular triserial series in 4–6 whorls, the last few chambers may be irregular; sutures distinct, depressed; wall smooth, finely perforate, initial two-thirds of the test very finely costate; aperture very small, usually in the depression at the junction of the last three sutures, somewhat comma-shaped.

*Dimensions.*—Length 0.16–0.34 mm.; diameter 0.09–0.14 mm.

*Type material.*—The holotype (Cat. No. P41641) (Plate 66, figures 20 a, b) measures 0.23 mm. in length, and 0.14 mm. in diameter; from sample C1, middle Headon beds, Colwell Bay. In all, 18 specimens were collected from seven samples from the Colwell Bay section.

*Type locality.*—Locality No. 2, Colwell Bay, about midway between Colwell and Bramble Chines, Isle of Wight. The species is restricted to seven samples from the base of the middle Headon beds (bluish-green sands and clays) with *Theodoxus concavus*, etc. The associaed faunule consists dominantly of *Nonion depressulum*, *Rotalia viennensis*, and *Valvulineria araucana*.

*Geologic age.*—Lower Oligocene, Lattorfian.

*Discussion.*—The variety differs from the typical form in that the initial end is rounded and the wall is finely costate in the earlier portion. It is closely allied to *Bulimina versa* Cushman and Parker, but differs from it in (a) the more regular arrangement of the chambers, (b) the lack of a basal spine, and (c) the finely perforate wall.

*Remarks.*—The varietal name is derived from the type locality to which the variety is restricted.

Genus ENTOSOLENIA Ehrenberg, 1848
ENTOSOLENIA LAEVIGATA (Reuss)
Plate 66, figure 12

*Fissurina laevigata* REUSS, 1849, Denkschr. K. Akad. Wiss. Wien, vol. 1, p. 366, pl. 46, figs. 1a, b.

*Lagena laevigata* (Reuss) TERRIGI, 1880, Atti Acad. Pont. Nuovi Lincei, vol. 33, p. 177, pl. 1, fig. 6; CUSHMAN, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 28, pl. 5, figs. 1, 2 (*et syn.*).

*Entosolenia laevigata* (Reuss) CUSHMAN, 1944, Cush. Lab. Foram. Res., Spec. Publ. 12, p. 28, pl. 4, fig. 12.

*Distribution.*—Rare to frequent in three samples (W8, W9, W12) from the Brockenhurst beds, Whitecliff Bay, and in two samples (HA2, HA3), from the base of the Hamstead *Corbula* beds.

*Range.*—Eocene to Recent.

Subfamily VIRGULININAE
Genus BITUBULOGENERINA Howe, 1934
BITUBULOGENERINA RETICULATA
Cushman
Plate 66, figure 16

*Bitubulogenerina reticulata* CUSHMAN, 1936, Cush. Lab. Foram. Res., Spec. Publ. 6, p. 62, pl. 8, figs. 21a, b; MARKS, 1951, Contr. Cush.

Found. Foram. Res., vol. 2, pt. 2, p. 61, pl. 7, fig. 17.

*Distribution.*—Rare to common in almost all the samples from the basal Brockenhurst beds, Whitecliff Bay.

*Range.*—Oligocene to Miocene.

### Genus BOLIVINA d'Orbigny, 1839
### BOLIVINA BEYRICHI Reuss var. BITUMINOSA Spandel
### Plate 66, figure 14

*Bolivina beyrichi* Reuss var. *bituminosa* SPANDEL, 1909, Offenbach ver. Nat. Ber., No. 43–50 (1901–1909), p. 207, pl. 1, fig. 14.
*?Bolivina böttgeri* SPANDEL, 1909, *ibid.*, p. 207, pl. 1, figs. 15a, b.

*Distribution.*—Frequent to common in four samples (HA5, HA6, HA7, HA9) from the Hamstead *Corbula* beds.

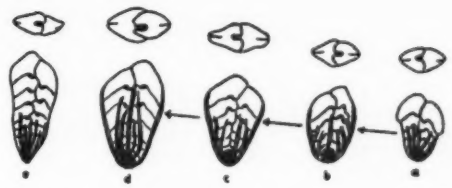
*Range.*—Oligocene.

*Discussion.*—The variety is distinguished from *B. beyrichi* by the more rounded periphery, the more strongly curved and oblique sutures, and the lack of spiny projections on the margins of the chambers.

### BOLIVINA FASTIGIA Cushman
### Plate 66, figure 15, Text-figures 5a-e

*Bolivina fastigia* CUSHMAN, 1936, Cush. Lab. Foram. Res., Spec. Publ. 6, p. 51, pl. 7, figs. 17a, b; 1937, Cush. Lab. Foram. Res., Spec. Publ. 9, p. 76, pl. 9, figs. 12–14.

The species occurs in great abundance in the Hamstead *Corbula* beds, and a large number of specimens were collected so that the range of variation could be studied. It is evident from the figures given (Text-fig. 5a–e) that the species varies considerably, both individually and also within the two dimorphic generations. None of the characters stated by Cushman to be distinctive of this species, such as median carina and sutures with distinct lobes, were found to be constant. The most variable characters are the shape of the tests and the number of surface costae. The megalospheric forms (Text-fig. 5a–d) are 1½–2 times as long as broad, tapering and possessing 8 (or less) pairs of chambers. Surface ornamentation consists usually of a median ridge and 2 or 3 supplementary costae on either side. Usually the periphery is keeled, except in young forms (Text-fig. 5a) in which it is often subacute. Representative specimens intermediate between the young and adult forms were also found. The microspheric



TEXT-FIG. 5—Dimorphism in *Bolivina fastigia* Cushman, from the Hamstead *Corbula* beds, Hamstead Hill; ×56. Illustrations *a-d* represent the megalospheric generation, *e* the microspheric generation.

forms (Text-fig. 5e) are less tapering with subacute initial end and they have 9 or 10 pairs of chambers. The inner lobes may in many cases be absent, and the costae are confined to the initial portion. The median ridge is absent.

*Distribution.*—Rare in samples W8 and W12 from the Brockenhurst beds, and abundant in most of the samples from the Hamstead *Corbula* beds.

*Range.*—Oligocene to Miocene.

### BOLIVINA VARIABILIS (Williamson)
### Plate 66, figure 13

*Textularia variabilis* WILLIAMSON, 1858, Recent Foram. Gt. Britain, p. 76, pl. 6, figs. 162–163.
*Bolivina variabilis* (Williamson) CHASTER, 1892 [1890–1891], Southport Soc. Nat. Sci., First Rept., p. 59; CUSHMAN, 1937, Cush. Lab. Foram. Res., Spec. Publ. 9, p. 158, pl. 16, figs. 6, 12–14 (*et syn.*).

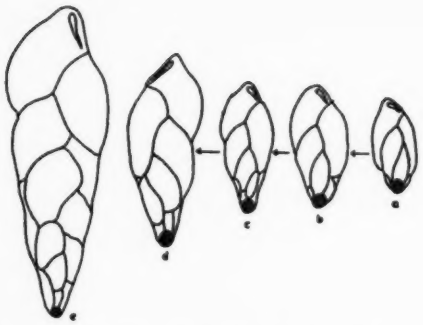
*Distribution.*—Rare in samples W8 and W12 from the Brockenhurst beds, and abundant in most of the samples from the Hamstead *Corbula* beds.

*Range.*—Oligocene to Recent.

### Genus VIRGULINA d'Orbigny, 1826
### VIRGULINA SCHREIBERSIANA Czjzek
### Plate 66, figure 24, Text-figures 6a–e

*Virgulina schreibersiana* CZJZEK, 1847, Haid. Nat. Abh., p. 147, figs. 18–21; CUSHMAN, 1937, Cush. Lab. Foram. Res., Spec. Publ. 9, p. 13, pl. 2, figs. 11–20 (*et syn.*).

Typical specimens, identical with those from the Miocene of the Vienna Basin, were found in the Hamstead *Corbula* beds and a large number of individuals were studied. The two dimorphic generations were recognized (Text-fig. 6a–e). In the megalospheric forms, the test is 2–2½ times as long as broad, the chambers inflated, elongate, strongly embracing and extending down to the initial portion, at least in young forms.



TEXT-FIG. 6—*Virgulina schreibersiana* Czjzek, from the Hamstead *Corbula* beds, Hamstead Hill; ×55. The megalospheric, *a–d*, and microspheric, *e*, generations.

With growth, however, the succeeding chambers are further removed from the base. The microspheric forms (Text-fig. 6e) are large and more elongate, 3 times longer than broad. The chambers are numerous, comparatively stout, and less embracing, each succeeding one further removed from the initial portion. Text-figures 6a–d show the various growth stages in the megalospheric generation.

*Distribution.*—Frequent to common in three samples (HA6, HA7, HA9) from Hamstead *Corbula* beds.

*Range.*—Oligocene to Recent.

Subfamily UVIGERININAE
Genus ANGULOGERINA Cushman, 1927
ANGULOGERINA TENUISTRIATA (Reuss)
Plate 66, figures 18a, b

*Uvigerina tenuistriata* REUSS, 1870, Sitzungsber. k. Akad. Wiss. Wien, vol. 62, p. 485; VON SCHLICHT, 1870, Foram. Septar. Pietzpuhl, pl. 22, figs. 34–37.

*Angulogerina tenuistriata* (Reuss) CUSHMAN and EDWARDS, 1938, Contr. Cush. Lab. Foram. Res., vol. 14, pt. 4, p. 84, pl. 15, figs. 1–7.

*Distribution.*—Common in two samples (HA7, HA9) from the Hamstead *Corbula* beds.

*Range.*—Oligocene.

*Discussion.*—There are numerous records of this species ranging from Oligocene to Recent, but many are not the same as the one described by Reuss. Most authors seem to have accepted Brady's figures in the *Challenger* Report (1884), but these forms represent entirely different species. Brady's specimens, which belong to the genus *Uvigerina*, were compared with topotype specimens of *A. tenuistriata*. The former are distinct in having rounded and inflated chambers and in the absence of keels. The neck and aperture are also quite different.

ANGULOGERINA aff. A. OLIGOCAENICA (Andreae) var. GLOBOSA (Stoltz)
Plate 66, figure 19

The specimen figured from sample HA7 of the Hamstead *Corbula* beds may be questionably referred to this variety. The test is elongate, three times as long as broad; the sides are almost parallel throughout; and the last few chambers are smooth.

Family ROTALLIDAE
Subfamily DISCORBINAE
Genus DISCORBIS Lamarck, 1804
DISCORBIS BEMBRIDGENSIS Bhatia, n. sp.
Plate 66, figures 26a–c

*Diagnosis.*—Test minute, compressed trochospiral; periphery rounded, lobulate. Dorsal side slightly convex, sometimes flat, with 2–2½ whorls visible; ventral side somewhat concave, with umbilicus usually filled with secondary shell material, running slightly into the sutures. Chambers 6–8 in the last whorl, slightly inflated; sutures depressed, almost straight and oblique on the dorsal side, gently curved on the ventral. Wall smooth, rather coarsely perforate; aperture indistinct, obscured by the filling on the ventral side.

*Dimensions.*—Diameter 0.18–0.25 mm.; thickness 0.10–0.14 mm.

*Type material.*—The holotype (Cat. No. P41645) (Pl. 66, fig. 26a–c) measures 0.23 mm. in diameter, and 0.14 mm. in thickness; from sample B2, Bembridge oyster beds. In all, 17 specimens were collected.

*Type locality.*—Locality No. 4, near Bembridge Ledge, Whitecliff Bay. The type specimens are from the basal part of the Bembridge oyster beds, whitish-green sands with interstratified clay. The oyster beds immediately overlie the fresh-water compact marls, usually grouped with the underlying Bembridge limestone. The associated faunule consists dominantly of *Nonion depressulum* and *Buliminella striatopunctata*.

*Geologic age.*—Lower Oligocene, Lattorfian.

*Discussion.*—The compressed test, straight oblique sutures on the dorsal side and the umbilical filling on the ventral side are distinctive of this species.

*Remarks.*—The trivial name is derived from the Bembridge oyster beds, to which the species is restricted.

DISCORBIS cf. D. RUGOSA (d'Orbigny)
Plate 66, figures 25a, b

Four specimens were found in sample HH2 from the middle Headon beds, Headon Hill, that may be doubtfully referred to *Discorbis rugosa* (d'Orbigny).

Genus VALVULINERIA Cushman, 1926
VALVULINERIA ARAUCANA (d'Orbigny)
Plate 67, figures 1a–c

*Rosalina araucana* D'ORBIGNY, 1839, Voy. Amér. Mérid., vol. 5, pt. 5, p. 44, pl. 6, figs. 16–18.
*Discorbina araucana* (d'Orbigny) PARKER and JONES, 1872, Quart. Jour. Geol. Soc., vol. 28, p. 115.
*Discorbis araucana* (d'Orbigny) CUSHMAN, 1915, U. S. Nat. Mus. Bull. 71, pt. 5, p. 15, pl. 9, fig. 3.
*Valvulineria araucana* (d'Orbigny) CUSHMAN, 1927, Bull. Scripps Inst. Oceanogr., Tech. Ser., vol. 1, no. 10, p. 160, pl. 4, figs. 7, 8.
*Discorbis araucana* (d'Orbigny) MARKS, 1951, Contr. Cush. Found. Foram. Res., vol. 2, pt. 2, p. 63.

*Distribution.*—Common in the basal samples from the middle Headon beds at Headon Hill and Colwell Bay; a single specimen was found in the Whitecliff Bay section (W30). In the Hamstead *Corbula* beds, this species is rare to frequent in the two basal samples (HA1, HA3). The figured specimens are from sample HH2, Headon Hill.

*Range.*—Oligocene to Recent.

*Remarks.*—Brady's *Challenger* specimens (1884) of *Discorbina araucana* were examined at the British Museum (Natural History). Although these specimens resemble d'Orbigny's figures, the sutures are limbate in some specimens and the test is not so coarsely perforate as in the illustrations.

VALVULINERIA SUBCONICA (Terquem)
Plate 67, figures 2a, b

*Rotalina subconica* TERQUEM, 1882, Mém. Soc. Géol. France, sér. 3, vol. 2, p. 61, pl. 4, figs. 5a–c.
*Valvulineria subconica* (Terquem) LE CALVEZ, 1949, Serv. Carte. Géol. Mém., Paris, II, p. 26, pl. 5, figs. 87–89 (*et syn.*).

*Distribution.*—Rare to frequent in four samples (W8, W15, W16, W17) from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Lower Oligocene.

*Discussion.*—This species seems to link the genera *Baggina* and *Valvulineria*. It possesses the characteristics of both groups and may well be placed in either. However, the Isle of Wight specimens were compared with specimens from Grignon, Paris Basin, and the two are identical. In a few specimens from the former material, the flap is broken or not well developed.

Subfamily ROTALIINAE
Genus EPONIDES Montfort, 1808
EPONIDES cf. E. PYGMEUS (Hantken)
Plate 67, figures 7a–c

A few specimens which may be doubtfully referred to *E. pygmeus* (Hankten), were found in the two basal samples (W8, W9) from the Brockenhurst beds, Whitecliff Bay.

Genus PARAROTALIA Le Calvez, 1949
PARAROTALIA SUBINERMIS Bhatia, n. sp.
Plate 67, figures 3a–c

*Diagnosis.*—Test trochoid compressed, usually equally biconvex, but sometimes the dorsal side may be flat. Periphery slightly lobulate. Young forms occasionally with small spiny projections, subacute, with a keel of fine granular shell material. Dorsal side with 2½ whorls visible, 7–9 chambers in the last one. Dorsal sutures slightly curved, not depressed, strongly limbate, of clear shell material; ventral sutures gently curved, strongly depressed, prominent umbo in the center. Wall finely perforate; aperture small, elliptical, midway between periphery and umbo, near the base of the last chamber, with a faint lip.

*Dimensions.*—Maximum diameter 0.90 mm.; thickness 0.40 mm.

*Type material.*—The holotype (Cat. No. P41644) (Pl. 67, fig. 3a-c) measures 0.86 mm. in diameter, and 0.34 mm. in thickness. From sample W16, Brockenhurst beds.

*Type locality.*—Locality No. 5, Whitecliff Bay. The types are from the Brockenhurst beds, brown sandy clay. The associ-

ated faunule consists dominantly of *Rotalia canui*, *Cibicides aknerianus*, and *Valvulineria subconica*.

*Geologic age.*—Lower Oligocene, Lattorfian.

*Discussion.*—The species was compared with topotype specimens of *P. inermis* (Terquem), kindly sent by Mme. Le Calvez, of the university of Rennes, France. It differs from *P. inermis* in the more compressed test, strongly limbate dorsal sutures, and the polygonal shape of the chambers.

Genus ROTALIA Lamarck, 1804

ROTALIA CANUI Cushman

Plate 66, figures 32 a–c

*Rotalia canui* CUSHMAN, 1928, Foraminifères du Stampien du Bassin de Paris, Soc. Sci. Seine-et-Oise, Bull., Versailles, sér. 2, tome 9, p. 55, pl. 3, figs. 2a–c (*et syn.*).

A large number of forms closely allied to *R. canui* have been described by various authors under different names. It is therefore difficult to give an adequate synonymy or an exact distribution without studying the actual topotype specimens.

*Distribution.*—Frequent in five samples (W12, W15–W18) from the Brockenhurst beds.

*Range.*—Eocene?, Oligocene.

*Discussion.*—As already remarked, the species has probably been recorded under several different names. Some of the closely allied forms are *Rotalia armata* d'Orbigny and *Globorotalia spinigera* (Terquem) Le Calvez. Some topotype specimens of *Rotalia armata* were examined. These are comparatively stouter than the present species and have a "pararotalia"-like aperture. Topotype specimens of *G. spinigera* appear to be closely allied to this species, except that the umbo is absent. However, it was not possible to study a large number of individuals of this related species, and it is difficult to determine the extent of variation. For the present, *G. spinigera* is considered to be a different species.

ROTALIA VIENNENSIS (d'Orbigny)

Plate 66, figures 30a–c

*Rosalina viennensis* D'ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 177, pl. 10, figs. 22–24.

*Rotalia viennensis* (d'Orbigny) MARKS, 1951, Contr. Cush. Found. Foram. Res., Vol. 2, pt. 2, p. 65, pl. 8, figs. 7a–c (*et syn.*).

*Distribution.*—Excluding *Nonion depressulum*, this is the most common species in the middle Headon beds of the Isle of Wight. It is frequent to abundant in the majority of samples from these beds at Colwell Bay, Headon Hill, and also from the "*Venus* beds" of the Whitecliff Bay section.

*Range.*—Oligocene to Miocene.

ROTALIA aff. R. PAPILLOSA d'Orbigny (*non* Brady)

Plate 66, figures 31a–c

This species may be questionably referred to *R. papillosa* d'Orbigny (*non* Brady) from the Tertiary of the Paris Basin. Rare to common in almost all the samples from the middle Headon beds of Headon Hill and Colwell Bay sections. It occurs irregularly and less frequently in the Whitecliff Bay section.

ROTALIA sp. indet.

Plate 66, figures 33a–c

This rather obscure species was found only in the two basal and in two upper samples from the Bembridge oyster beds. Rare to common in occurrence.

Family AMPHISTEGINIDAE

Genus ASTERIGERINA d'Orbigny, 1839

ASTERIGERINA sp. indet.

Plate 67, figures 4a–c

Rare to frequent specimens of the species were found in a few samples from the Brockenhurst beds, Whitecliff Bay. The specimens are too minute and obscure to permit specific determination.

Family CASSIDULINIDAE

Subfamily CERATOBULIMININAE

Genus PSEUDOPARRELLA Cushman and ten Dam, 1948

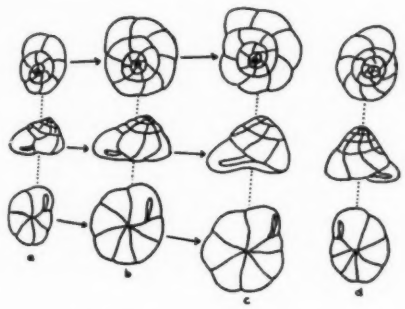
PSEUDOPARRELLA OVEYI Bhatia, n. sp.

Plate 66, figures 29a–c, Text-figures 7a-d

*Diagnosis.*—Test minute, trochoid; dorsal side strongly convex, ventral side flat; umbilicus closed; periphery slightly lobulate, subacutely rounded. Dorsally $2\frac{1}{2}$–4 whorls visible, closely coiled, 6–8 chambers in the last whorl, slightly inflated, gradually increasing in size with growth. Sutures slightly depressed, somewhat limbate and oblique on the dorsal side, straight or somewhat sigmoid on the ventral. Wall smooth, finely

perforate; aperture elongate, ventral, somewhat loop-shaped in the plane of coiling.

A very large number of individuals were examined and two dimorphic generations were recognized. In the microspheric forms, which are rare, the test is of medium size, and strongly convex or conical on the dorsal side, on which four closely coiled whorls are visible. The megalospheric forms have 2½–3½ whorls, which are not so closely coiled as in the microspheric forms; the test is also not so conical. The size of the megalospheric proloculum varies. Text-figures 7a–c show growth stages in the megalospheric generation.



TEXT-FIG. 7—*Pseudoparrella oveyi* Bhatia, n. sp., from the Hamstead *Corbula* beds, Hamstead Hill, ×61. The megalospheric, *a-c*, and microspheric, *d*, generations.

*Dimensions.*—Maximum diameter 0.20 mm., thickness or height 0.16 mm.

*Type material.*—The holotype (Cat. No. P41640) (Pl. 66, fig. 29a-c) measures 0.18 mm. in diameter and 0.16 mm. in thickness. In all, 41 specimens were found distributed among three samples (HA2, HA7, HA9) from the Hamstead *Corbula* beds.

*Type locality.*—Locality No. 3, Hamstead Hill. The holotype is from sample HA7, a stiff bluish-black clay in which *Corbula subpisum* is abundant. The associated faunule consists dominantly of *Bulimina* spp., *Bolivina variabilis*, *B. fastigia*, and *Angulogerina tenuistriata*.

*Geologic age.*—Middle Oligocene, Rupelian.

*Discussion.*—The species is easily recognized by its minute size and strongly convex dorsal side on which 2½ to 4 whorls are usually visible.

*Remarks.*—The species is named after Mr. C. D. Ovey, formerly of the British Museum (Natural History). The author has benefited much from his knowledge and thorough understanding of the foraminifers.

Family CHILOSTOMELLIDAE
Subfamily ALLOMORPHINELLINAE
Genus PULLENIA Parker and Jones, 1862
PULLENIA sp. indet.
Plate 66, figure 27

It is difficult to assign this representative of *Pullenia* to any known species. The number of chambers varies from 4–6, and the apertural face, together with aperture, is covered with secondary material. Frequent to abundant in almost all the samples from the Hamstead *Corbula* beds. Rare in four samples (W8, W9, W12, W28) from the middle Headon beds, Whitecliff Bay.

Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA sp. indet.
Plate 66, figures 28a, b

This indeterminate form is fairly abundant in three samples (W8, W9, W12) from the Brockenhurst beds, Whitecliff Bay.

Family ANOMALINIDAE
Subfamily CIBICIDINAE
Genus CIBICIDES Mortfort, 1808
CIBICIDES AKNERIANUS (d'Orbigny)
Plate 67, figures 5a–c

*Rotalina akneriana* D'ORBIGNY, 1846, Foram. Foss. Bassin Tert. Vienne, p. 156, pl. 8, figs. 13–15.
*Rotalia akneriana* D'ORBIGNY, 1852, Prodrome de Paléont., vol. 3, 26e Étage B, no. 2911.
*Truncatulina akneriana* REUSS, 1866, Denkschr. d. k. Akad. Wiss. Wien, vol. 25, p. 160, no. 6.
*Cibicides akneriana* (d'Orbigny) NUTTALL, 1932, Jour. Paleontology, vol. 6, p. 32, pl. 9, figs. 1–3.

*Distribution.*—Frequent to abundant in most of the samples from the Brockenhurst beds, Whitecliff Bay.

*Range.*—Eocene to Miocene. Recent records by Brady (1884) have been discredited (*vide etiam* Thalmann, 1932).

*Remarks.*—The Isle of Wight specimens are identical with the topotype specimens from the Miocene of the Vienna Basin.

TABLE 1.—PER CENT DISTRIBUTION OF FORAMINIFERA, MIDDLE HEADON BEDS, WHITECLIFF BAY

| Foraminiferal Species \ Sample Nos. | Brockenhurst Zone | | | | Roydon Zone | | | | | | | Barren Sands | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W 8 | W 9 | W 10 | ■ W 11 | W 12 | ● W 13 | ● W 14 | W 15 | W 16 | W 17 | W 18 | ● W 19 | ● W 20 | ● W 21 | ● W 22 | ● W 23 |
| *Clavulina angularis* d'Orbigny | 0.2 | | | | | | | | 0.2 | | | | | | | |
| *Miliolinella oblonga* (Montagu) | | | | | | | | 2.1 | | | | | | | | |
| *Quinqueloculina bicarinata* d'Orbigny | | | | | | | | 1.5 | | | | | | | | |
| *Quinqueloculina impressa* var. *cognata* (Borne.) | | | | | | | | 2.8 | | | | | | | | |
| *Quinqueloculina pertusa* Terquem | | | | | | | | 1.3 | | | | | | | | |
| *Quinqueloculina juleana* d'Orbigny | | | | | 26.9 | | | | | | | | | | | |
| *Quinqueloculina seminulum* (Linné) | | | | | 0.7 | | | 2.6 | | | | | | | | |
| *Quinqueloculina simplex* Terquem | | | | | | | | 0.1 | | | | | | | | |
| *Spiroloculina obscura* Cushman & Todd | | | | | | | | 0.5 | | | | | | | | |
| *Triloculina trigonula* (Lamarck) | | | | | 3.8 | | | 3.3 | | | 0.9 | | | | | |
| *Glandulina laevigata* d'Orbigny | | | | | | | | | | | 0.9 | | | | | |
| *Globulina ampulla* (Jones) | | 0.7 | | | | | | | | | | | | | | |
| *Globulina gibba* d'Orbigny | 0.8 | | | | 0.7 | | | 0.1 | | 1.2 | | | | | | |
| *Globulina gibba* var. *tuberculata* (d'Orb.) | 0.2 | | | | | | | | | | | | | | | |
| *Globulina inaequalis* Reuss | 1.9 | 2.8 | | | 0.7 | | | 1.1 | | | | | | | | |
| *Globulina* cf. *G. minuta* (Roemer) | 0.4 | 0.2 | | | | | | 0.1 | | | | | | | | |
| *Guttulina bulloides* (Reuss) | | | | | 0.3 | | | | | | | | | | | |
| *Guttulina irregularis* (d'Orbigny) | 1.0 | 1.4 | | | | | | | | | | | | | | |
| *Pyrulina* sp. indet. | | | | | | | | | | | | | | | | |
| *Sigmomorphina* sp. indet. | | 0.7 | | | 0.3 | | | | | | | | | | | |
| *Nonion depressulum* (Walker & Jacob) | 6.5 | 4.9 | 10.0 | | 3.9 | | | | | | | | | | | |
| *Nonion laeve* var. *subexcavatum*, n. var. | 0.8 | 3.9 | 20.0 | | 1.8 | | | | | | | | | | | |
| *Nonion umbilicatulum* (Walker & Jacob) | 17.0 | 1.4 | | | 1.4 | | | 1.1 | | | | | | | | |
| *Elphidium minutum* (Reuss) | 2.7 | 2.8 | | | 3.2 | | | | | | | | | | | |
| *Buliminella carteri*, n. sp. | | | | | | | | | | | | | | | | |
| *Bulimina coprolithoides* Andreae | | | | | | | | | | | | | | | | |
| *Entosolenia laevigata* (Reuss) | 1.0 | 4.9 | | | 0.7 | | | | | | | | | | | |
| *Bitubulogenerina reticulata* Cushman | 1.9 | 4.9 | 10.0 | | 4.8 | | | 0.5 | | 1.2 | 5.6 | | | | | |
| *Bolivina fastigia* Cushman | 1.2 | | | | 1.0 | | | | | | | | | | | |
| *Bolivina variabilis* (Williamson) | 3.2 | | | | 2.1 | | | | | | | | | | | |
| *Valvulineria araucana* (d'Orbigny) | | | | | | | | | | | | | | | | |
| *Valvulineria subconica* (Terquem) | 0.4 | | | | | | | 1.5 | 2.5 | 4.8 | | | | | | |
| *Eponides* cf. *E. pygmeus* (Hantken) | 1.9 | 5.2 | | | | | | | | | | | | | | |
| *Pararotalia subinermis*, n. sp. | | | | | | | | 71.3 | 69.5 | 70.7 | 15.4 | | | | | |
| *Rotalia* aff. *R. papillosa* d'Orbigny | 2.9 | 2.8 | | | 1.0 | | | 0.8 | | 1.2 | | | | | | |
| *Rotalia canui* Cushman | | | | | 3.2 | | | 7.7 | 15.3 | 21.9 | 71.6 | | | | | |
| *Rotalia viennensis* (d'Orbigny) | | | | | | | | | | | | | | | | |
| *Asterigerina* sp. indet. | 0.6 | | | | 1.4 | | | 0.1 | | | 0.9 | | | | | |
| *Pullenia* sp. indet. | 0.4 | 5.2 | | | 1.4 | | | | | | | | | | | |
| *Globigerina* sp. indet. | 27.1 | 26.3 | | | 22.2 | | | | | | | | | | | |
| *Cibicides aknerianus* (d'Orbigny) | 27.5 | 29.8 | 60.0 | | 17.5 | | | 1.5 | 12.5 | | 1.8 | | | | | |
| *Cibicides refulgens* Montfort | 10.6 | 2.1 | | | | | | | | | 2.9 | | | | | |

■ Foraminifera not identifiable. ● Only miliolid casts present. ▲ Foraminifera absent.

TABLE 1—*Continued*

| | | | | "*Venus*" Beds | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● W 24 | ● W 25 | ▲ W 26 | ▲ W 27 | W 28 | W 29 | W 30 | W 31 | W 32 | W 33 | W 34 | W 35 | W 36 | W 37 | W 38 | ▲ W 39 | W 40 | W 41 | W 42 | ▲ W 43 | ▲ W 44 | ▲ W 45 | ▲ W 46 |
| | | | | | | | | 0.8 | 3.5 | | | | | | | | | | | | | |
| | | | | | | | 0.1 | 15.9 | 3.5 | | | | | | | 1.0 | 19.8 | | | | | |
| | | | | | | | | | 7.1 | | | | | | | | 3.1 | | | | | |
| | | | | | 0.8 | | | | | | | | | | | | | | | | | |
| | | | | | 0.2 | | | | | | | | | | | | | | | | | |
| | | | | 3.8 | | | | | | | | | | | | | | | | | | |
| | | | | 13.7 | 18.0 | 8.0 | 82.4 | 63.9 | 7.4 | 12.5 | 56.7 | 78.2 | 100 | 100 | | 98.0 | 75.9 | 100 | | | | |
| | | | | | | | 0.5 | | | | | | | | | | | | | | | |
| | | | | | 0.5 | 88.0 | | | | | 4.3 | 15.0 | | | | | | | | | | |
| | | | | | 0.2 | | | | | | | | | | | | 0.1 | | | | | |
| | | | | | | 2.0 | | | | | | | | | | | | | | | | |
| | | | | 31.0 | 19.5 | | 8.5 | 10.8 | | | 8.6 | 3.4 | | | | | | | | | | |
| | | | | 37.9 | 60.3 | 2.0 | 8.5 | 8.6 | 78.5 | 87.5 | 30.4 | 3.4 | | | | 1.0 | 1.1 | | | | | |
| | | | | 6.8 | 0.5 | | | | | | | | | | | | | | | | | |
| | | | | 6.8 | | | | | | | | | | | | | | | | | | |

CIBICIDES REFULGENS Montfort
Plate 67, figures 6a–c

*Hammonia Balanus seu Balanoidea* SOLDANI, 1789, Testaceographia, vol. 1, pt. 1, p. 58, pl. 46, figs. nn, oo.

*Cibicides refulgens* MONTFORT, 1808, Conchyliologie Systématique et classification méthodique de coquilles; Paris, F. Schoell, vol. 1, p. 123, 31me. genere.

*Truncatulina refulgens* (Montfort) D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 279, pl. 13, figs. 8–11, modèles, no. 77, IVe livr.

*Cibicides refulgens* (Montfort) CUSHMAN, 1928, Cush. Lab. Foram. Res., Spec. Publ. 1, pl. 50, figs. 2a–c; 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 116, pl. 21, figs. 2a–c (*et syn.*).

*Distribution.*—Rare to abundant in three samples (W8, W9, W18) from the Brockenhurst beds. Single specimens were also found in 2 samples (HH10, HH13) from the middle Headon beds at Headon Hill.

*Range.*—Eocene to Recent.

### FAUNAL ANALYSIS

Because the marine Oligocene beds of the Isle of Wight are not highly productive in foraminifers, the total number of species found in these beds is small compared with the number in contemporaneous horizons in the European Tertiary. For this same reason, the number of species common to the Oligocene of the two areas is also very small. Exact correlation on the basis of common species is therefore difficult, and it is necessary to apply the criterion of the known stratigraphic ranges of species. Only the first appearance of a species, coupled with its known ranges throughout limited stratigraphical thickness can be used effectively in any inter-regional correlations.

A statistical analysis of the various species found in the Oligocene beds of the Isle of Wight based on the above principles reveals certain interesting features which are listed below.

1. *Foraminiferal fauna of the middle Headon beds*—47 species and varieties (Tables 1–3).
   a. Four species and varieties are new and therefore of little value at the moment for correlation purposes.
   b. Seventeen species and varieties have a long geologic range—either Eocene to Miocene or Eocene to Recent. *Lagena sulcata* is known to range from Cretaceous to Recent.
   c. *Quinqueloculina bicarinata* has so far been recorded only from the Pliocene and Recent of Italy.
   d. Nine species are known to appear *first* in the Oligocene and to range upward to Miocene or Recent. These are *Clavulina angularis, Nonion depressulum, Elphidium minutum, Rotalia viennensis, Valvulineria araucana, Bolivina variabilis, B. fastigia, Bitubulogenerina reticulata* and *Quinqueloculina juleana.*
   e. Three forms are found in the Oligocene of Germany and France, namely *Bulimina coprolithoides, Quinqueloculina impressa* var. *cognata,* and *Rotalia canui.* Except for one record of *B. coprolithoides* (Selli, 1944) from the Eocene beds of Italy, it is a characteristic Oligocene species.
   f. Five species occur in the Eocene of the Paris Basin, namely *Quinqueloculina simplex, Q. pertusa, Globulina ampulla, Buliminella striatopunctata,* and *Valvulineria subconica.*
   g. The ranges of the rest of the species and varieties are doubtful.
2. *Foraminiferal fauna of the Bembridge oyster beds*—10 species (Table 4).
   a. Two species are new.
   b. *Bulimina pupoides, Buliminella elegantissima* and *Miliolinella oblonga* range from Eocene to Recent.
   c. *Nonion depressulum* ranges from Oligocne to Recent.
   d. *Bulimina coprolithoides* occurs in the Oligocene strata of Germany and France.
   e. *Buliminella striatopunctata* occurs in the Eocene beds of the Paris Basin.
   f. The rest of the species are too obscure for definite identifications.
3. *Foraminiferal fauna of the Hamstead* Corbula *beds*—24 species and varieties (Table 5).
   a. Two new species.
   b. Eight species range from Eocene to Recent.
   c. *Nonionella auricula* has so far been recorded only from Recent seas.
   d. Eight species have been recorded from characteristic Oligocene deposits in Germany, France, and other countries, and range upward to Miocene or Recent.
   e. Three species are characteristic Oligocence forms: *Angulogerina tenuistriata, Bolivina beyrichi* var. *bituminosa,* and *Bulimina coprolithoides.*
   f. Only one species, *Quiqueloculina simplex,* ranges up from the Eocene.
   g. The identification of the other species is provisional.
   h. The fauna of the Hamstead *Corbula* beds is very similar to the one described by Paalzow (1924), from the Middle Oligocene, Cerithien sands of Offenbach, Germany, and seven species are common to both.
   i. Three species are identical with those described by Spandel (1909) from the Rupelton beds of the Mainz Basin, Germany.
   j. Three species are identical with those described by Reuss (1870) from the Middle Oligocene, Septarienthon of Pietzpuhl, Germany.
   k. Two species are identical with those described by Cushman (1928) from the Oligocene (Stampien) of the Paris Basin, France.

TABLE 2.—PER CENT DISTRIBUTION OF FORAMINIFERA, MIDDLE HEADON BEDS, HEADON HILL

TABLE 2.—PER CENT DISTRIBUTION OF FORAMINIFERA, MIDDLE HEADON BEDS, HEADON HILL

| Foraminiferal Species \ Sample Nos. | HH 1 | HH 2 | ▲HH 3 | ▲HH 4 | ▲HH 5 | HH 6 | HH 7 | HH 8 | HH 9 | HH 10 | HH 11 | HH 12 | HH 13 | HH 14 | HH 15 | HH 16 | ▲HH 17 | HH 18 | ▲HH 19 | HH 20 | ▲HH 21 | HH 22 | ▲HH 23 | HH 24 | HH 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Miliolinella oblonga* (Montagu) | | | | | | | | | | | 1.0 | | | | | | | 0.7 | | | | | | | |
| *Lagena sulcata* (Walker & Jacob) | | | | | | | | | | | 0.2 | | | | | | | | | | | | | | |
| *Guttulina bulloides* (Reuss) | | | | | | | | 0.2 | | | | | | | | | | | | | | | | | |
| *Nonion depressulum* (Walker & Jacob) | 56.6 | 0.6 | | | | 50.6 | 55.8 | 56.9 | 40.5 | 49.3 | 36.6 | 40.8 | 55.8 | 44.0 | 55.0 | 59.7 | | 86.9 | | 33.4 | | 33.4 | | 98.1 | 92.4 |
| *Elphidium minutum* (Reuss) | | | | | | 7.5 | 8.7 | 3.5 | 6.0 | 5.0 | 3.6 | 1.7 | 7.5 | 6.6 | 5.5 | 1.7 | | | | | | | | | |
| *Buliminella carteri*, n. sp. | | | | | | 0.5 | 0.5 | 0.7 | 0.2 | | | | 0.3 | | | 0.5 | | 0.1 | | | | | | | |
| *Buliminella elegantissima* (d'Orbigny) | | | | | | | | | | | | | 0.1 | | | | | | | | | | | | |
| *Bulimina coprolithoides* Andreae | | | | | | 2.3 | 0.5 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 | 0.5 | 0.4 | 0.2 | 1.7 | | 0.7 | | 33.3 | | | | 1.6 | |
| *Discorbis* cf. *D. rugosa* (d'Orbigny) | | 0.5 | | | | | | | | | | | | | | | | 11.5 | | 33.3 | | | | | |
| *Valvulineria araucana* (d'Orbigny) | 43.4 | 98.4 | | | | 13.8 | 10.3 | 11.2 | 10.6 | 8.5 | 8.4 | 16.3 | 8.2 | 5.5 | 16.3 | 3.0 | | 0.1 | | | | 33.3 | | 0.3 | |
| *Rotalia* aff. *R. papillosa* d'Orbigny | | | | | | 25.3 | 24.2 | 27.3 | 42.4 | 36.8 | 50.0 | 40.9 | 27.3 | 43.5 | 23.0 | 33.4 | | | | | | 33.3 | | | 7.6 |
| *Rotalia viennensis* (d'Orbigny) | | 0.5 | | | | | | | | 0.1 | | | 0.3 | | | | | | | | | | | | |
| *Cibicides refulgens* Montfort | | | | | | | | | | | | | | | | | | | | | | | | | |

▲ Foraminifera absent.

TABLE 3.—PER CENT DISTRIBUTION OF FORAMINIFERA, MIDDLE HEADON BEDS, COLWELL BAY

| Foraminiferal Species \ Sample Nos. | C 1 | C 2 | C 3 | C 4 | C 5 | C 6 | C 7 | C 8 | C 9 | C 10 | C 11 | C 12 | C 13 | C 14 | C 15 | C 16 | C 17 | C 18 | C 19 | C 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Miliolinella oblonga* (Montagu) | 0.5 | 2.9 | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina seminulum* (Linné) | | 0.9 | 1.2 | 8.6 | 2.8 | 0.1 | | | 0.8 | | | | | | | 1.1 | | | | |
| *Quinqueloculina simplex* Terquem | | | | | | | | | | | | | | | | | | | | |
| *Nonion depressulum* (Walker & Jacob) | 62.2 | 76.6 | 30.4 | 41.8 | 52.5 | 32.8 | 50.8 | 34.0 | 22.9 | 25.6 | 26.9 | 25.7 | 16.5 | 66.1 | 96.1 | 83.5 | 98.3 | 100 | 96.1 | 99.0 |
| *Elphidium minutum* (Reuss) | | | | 2.1 | | 2.7 | | 5.0 | 2.0 | 0.8 | 0.8 | 1.4 | 0.1 | 1.2 | | 1.6 | 0.9 | | 3.0 | |
| *Buliminella carteri*, n. sp. | | | | | 1.8 | 4.9 | 3.0 | | | 0.3 | | 0.3 | 0.1 | | | 0.1 | 0.3 | | | 1.0 |
| *Buliminella striatopunctata* (Terquem) | 3.0 | 1.4 | 5.4 | 4.3 | 3.9 | 1.1 | 3.0 | | | | | | | | | | | | | |
| *Bulimina coprolithoides* Andreae | | 0.4 | | 2.1 | | | | | 0.2 | | 0.8 | 0.1 | 0.2 | | 0.2 | 0.7 | 0.3 | | 0.3 | |
| *Bulimina simplex* var. *colwellensis*, n. var. | 3.7 | 0.9 | 2.0 | 4.3 | 1.9 | 0.1 | | | | | | | | | | | | | | |
| *Valvulineria araucana* (d'Orbigny) | 10.5 | 7.0 | 48.2 | 8.6 | 14.2 | 1.7 | 12.3 | 5.0 | | | | | | 0.1 | 0.7 | 3.7 | | | | |
| *Rotalia* aff. *R. papillosa* d'Orbigny | 1.8 | 0.9 | | 2.1 | | | 1.6 | 1.6 | 3.5 | 6.2 | 5.5 | 5.1 | 3.6 | 10.1 | 0.2 | 1.9 | 0.2 | | 0.6 | |
| *Rotalia viennensis* (d'Orbigny) | 18.3 | 9.0 | 12.8 | 26.1 | 22.9 | 56.6 | 29.3 | 54.4 | 70.6 | 67.1 | 66.0 | 67.4 | 79.5 | 22.5 | 2.8 | 7.4 | | | | |

TABLE 4.—PER CENT DISTRIBUTION OF FORAMINIFERA, BEMBRIDGE OYSTER BEDS, WHITECLIFF BAY

| Foraminiferal Species \ Sample Nos. | B 1 | B 2 | B 3 | B 4 | B 5 | B 6 |
|---|---|---|---|---|---|---|
| *Miliolinella oblonga* (Montagu) | 12.0 | 1.5 | 5.5 | 44.9 | 4.4 | 0.3 |
| *Triloculina* cf. *T. consorbina* (d'Orbigny) | 2.1 | 0.2 | | 8.1 | | |
| *Nonion depressulum* (Walker & Jacob) | 54.1 | 86.3 | 94.5 | 30.8 | 72.8 | 83.5 |
| *Buliminella carteri*, n. sp. | | | | | | 2.9 |
| *Buliminella elegantissima* (d'Orbigny) | 0.9 | 1.6 | | | 1.0 | 0.2 |
| *Buliminella striatopunctata* (Terquem) | 29.0 | 5.3 | | 8.1 | 5.2 | 11.6 |
| *Bulimina coprolithoides* Andreae | 0.3 | 1.0 | | 8.1 | 1.0 | 0.2 |
| *Bulimina pupoides* d'Orbigny | 0.3 | 1.0 | | | | 0.6 |
| *Discorbis bembridgensis*, *n.* sp. | 0.3 | 0.1 | | | 11.5 | |
| *Rotalia* sp. indet. | 1.0 | 3.0 | | | 4.1 | 0.7 |

## CONCLUSIONS

The statistical analyses given in the previous section show that although 10.6% of the total foraminiferal species in the middle Headon beds are characteristic Eocene forms, 27.6% of the species are known to appear first in the Oligocene, and 6.3% of these are restricted to the Oligocene. The long-ranging species constitute 38.2% of the total species. As little reliance for correlation purposes could be placed on these long-ranging species, greater reliance should be placed on the younger forms ranging from Oligocene to Recent.

Although the fauna is to some extent of a transitional nature, it has in its elements a fairly large percentage of younger forms which have not been recorded from beds older than the Oligocene. The assembled data clearly indicate that the age of the middle Headon beds must be younger than Bartonian. As will be shown later, the Hamstead *Corbula* beds are of Middle Oligocene age. On this basis, the Headon and Bembridge series should be assigned to the Lower Oligocene.

The foraminiferal fauna of the Bembridge oyster beds is comparatively poor in the number of species and is hardly reliable for purposes of exact correlation. Only one characteristic Eocene species, *Buliminella striatopunctata*, was found in these beds. *Nonion depressulum* is known to range from Oligocene to Recent. *Bulimina coprolithoides* is known from characteristic Oligocene beds. Except for the new and doubtful species, the remainder are all long-ranging species, and caution must be applied in stratigraphical correlation.

The Hamstead *Corbula* beds contain a foraminiferal fauna distinctly higher in the stratigraphical sequence than those mentioned previously. Except for a solitary species, *Quinqueloculina simplex*, which ranges up from the Eocene, 45.8% of the species have definitely been recorded from Oligocene and succeeding horizons. Of these, 12.5% are known from the Oligocene beds of Germany, France, and other countries in Europe. The fauna shows very close affinities with that described from the Middle Oligocene of the Pietzpuhl and Mainz Basin in Germany.

Sandberger (1862), on the evidence of the molluscs from the Hamstead *Corbula* beds, regarded them as exact equivalents of the Middle Oligocene beds exposed at Jeurres, Weinheim, and Bergh. Von Koenen (1867a, p. 507; 1867b, p. 31) correlated these beds, along with the Bembridge series, with the Middle Oligocene beds of Hermsdorf, Sölingen, Cassel, Bünde, and other localities in Germany.

TABLE 5.—PER CENT DISTRIBUTION OF FORAMINIFERA, HAMSTEAD *CORBULA* BEDS, HAMSTEAD HILL

| Foraminiferal Species \ Sample Nos. | HA 1 | HA 2 | HA 3 | HA 4 | HA 5 | HA 6 | HA 7 | ▲ HA 8 | HA 9 | ▲ HA 10 | ▲ HA 11 | ▲ HA 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ammobaculites agglutinans* (d'Orbigny) | 84.1 | 63.6 | | | 6.5 | | | | | | | |
| *Miliolinella oblonga* (Montagu) | 5.9 | | 4.3 | | 4.3 | | 0.2 | | 0.5 | | | |
| *Quinqueloculina* sp. indet. | | | 3.9 | | | | | | | | | |
| *Quinqueloculina seminulum* (Linné) | | 5.1 | 2.4 | | | | 0.2 | | | | | |
| *Quinqueloculina simplex* Terquem | | | 1.4 | | | | | | | | | |
| *Guttulina austriaca* d'Orbigny | | | | | | | 0.1 | | | | | |
| *Nonion scaphum* (Fichtel & Moll) | | | | | | 0.6 | 0.6 | | | | | |
| *Nonion depressulum* (Walker & Jacob) | | 10.1 | 27.3 | | | 0.3 | 4.5 | | 10.1 | | | |
| *Nonionella auricula* Heron-Allen & Earland | | | | | | 2.1 | 3.0 | | 9.0 | | | |
| *Buliminella carteri*, n. sp. | 0.6 | 1.6 | | 33.3 | 4.3 | 12.0 | 6.3 | | 4.6 | | | |
| *Buliminella elegantissima* (d'Orbigny) | | 0.8 | 0.3 | | 8.6 | 0.6 | 0.9 | | 1.6 | | | |
| *Bulimina coprolithoides* Andreae | 1.0 | 10.0 | 1.2 | | 19.4 | 18.4 | 15.2 | | 5.9 | | | |
| *Bulimina elongata* d'Orbigny | | 1.7 | 0.1 | | 3.0 | 4.2 | 1.9 | | 0.8 | | | |
| *Bulimina pupoides* d'Orbigny | | | | | | | 0.8 | | | | | |
| *Entosolenia laevigata* (Reuss) | | 0.3 | 1.2 | | | | | | | | | |
| *Bolivina beyrichi* var. *bituminosa* Spandel | | | | | 18.2 | 2.1 | 1.6 | | 1.0 | | | |
| *Bolivina fastigia* Cushman | | | 0.7 | | 8.6 | 17.6 | 13.8 | | 38.3 | | | |
| *Bolivina variabilis* (Williamson) | 5.8 | 1.6 | 6.2 | 33.4 | 20.2 | 18.7 | 14.6 | | 10.9 | | | |
| *Virgulina schreibersiana* Czjzek | | | | | | 0.6 | 2.3 | | 2.9 | | | |
| *Angulogerina* aff. *A. oligocaenica* var. *globosa* | | | | | | | 0.1 | | | | | |
| *Angulogerina tenuistriata* (Reuss) | | | | | | | 4.4 | | 1.0 | | | |
| *Valvulineria aarucana* (d'Orbigny) | 2.6 | | 1.2 | | | | | | | | | |
| *Pseudoparrella oveyi*, n. sp. | | 3.2 | | | | | 1.0 | | 2.0 | | | |
| *Pullenia* sp. indet. | | 2.0 | 49.8 | 33.3 | 6.9 | 22.8 | 35.2 | | 10.6 | | | |
| (Embryonic polymorphs) | | | | | | | 0.3 | | 0.8 | | | |

▲ Foraminifera absent

The foraminifers, so far as they can be compared with other Oligocene horizons, indicate that the Hamstead *Corbula* beds are of Middle Oligocene age. As stated before, there is some limited foraminiferal evidence to suggest that the middle Headon beds and the Bembridge series should be retained in the Lower Oligocene. However, as Vaughan (1924, p. 704) pointed out, it must be borne in mind that the boundaries between the major divisions of the Tertiary in Europe are not firmly drawn anywhere. The upper boundary of the Eocene in England has been altered from time to time. The solution may well depend on the evidence obtained from the revision of other faunal groups.

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# *TYTTHODISCUS*, A NEW MICROFOSSIL GENUS FROM THE CALIFORNIA TERTIARY

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ABSTRACT—A new organic microfossil, *Tytthodiscus*, was discovered in Tertiary marine sediments in the San Joaquin Valley of California. Two species, *T. californiensis* and *T. chondrotus*, are described.

## INTRODUCTION

Two new species of organic microfossils were discovered in the Tertiary of the San Joaquin Valley in California. They are tiny saucer-shaped bodies characterized by thick walls composed of hexagonal segments. The affinities of the new genus, *Tytthodiscus*, are unknown, but these microfossils are assumed to be of marine origin.

Organic fossils are plant or animal organs or fragments composed of chitin, cellulose, or cellulose-like materials. These organic constituents are resistant to the action of non-oxidizing acids and alkalies, and the *Tytthodiscus* specimens are separated from the matrix of siliceous sediments by the hydrofluoric acid method used for the separation of fossil spores and pollen (Norem, 1953).

## SYSTEMATIC PALEONTOLOGY

### Genus TYTTHODISCUS Norem, n. gen.

*Type species: Tytthodiscus californiensis* Norem, n. sp.

*Description.*—Disk-shaped with rim slightly raised to form a shallow saucer. Wall thick and composed of elongated hexagonal segments with major axis perpendicular to surface. Segments solid or provided with small central tubule which may extend all or part-way through the wall. Surface smooth or uniformly granular. Size ranges from 25 to 200 microns in diameter, and wall thickness as seen in cross section at rim ranging from a twentieth to a tenth of total diameter.

*Remarks.*—The diagnostic wall segments that characterize these microfossils are difficult to see except in eroded specimens. Their existence, however, may be inferred from the triangular arrangement of the tubules and surface granules. In a grid made up of hexagonal units, the centers of three adjacent units form the apices of equilateral triangles. Therefore, the granules and tubules centering on those units are arranged in a triangular pattern. The over-all appearance is that of regular rows.

*Occurrence.*—To the best of the writer's knowledge, the genus does not occur outside of California. It has been found in subsurface samples from the Bakersfield-Wasco-Kettleman Hills area in the San Joaquin Valley and in surface samples from Point Conception near Santa Barbara, California.

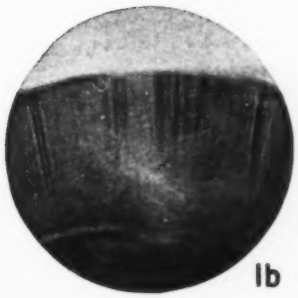
*Affinities.*—The origin of *Tytthodiscus* is not known. The fossils have been found in marine sediments only and are therefore assumed to have been part of a marine organism. *Tytthodiscus californiensis* resembles the Paleozoic spore? type, *Tasmanites* (Schopf, Wilson, and Bentall, 1944, p. 15). The representatives of *Tasmanites*,

### EXPLANATION OF PLATE 68

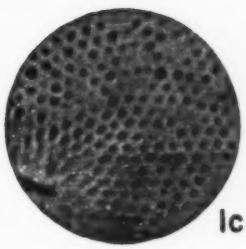
FIGS. *1a–1c—Tytthodiscus californiensis* Norem, n. sp. *1a* (×500), Holotype, USNM 40633, 167μ by 190μ, dark, irregular shadows are extraneous debris; *1b* (×1,000), cross section of wall, 22μ thick; *1c* (×1,000), pores. (p. 695)

*2a–2c—T. chondrotus* Norem, n. sp. *2a* (×500), Holotype, USNM 40632, 117μ by 126μ, dark irregular shadows are extraneous debris; *2b* (×1,000), granules under high focus, *2c* (×1,000), pores under low focus. (p. 695)

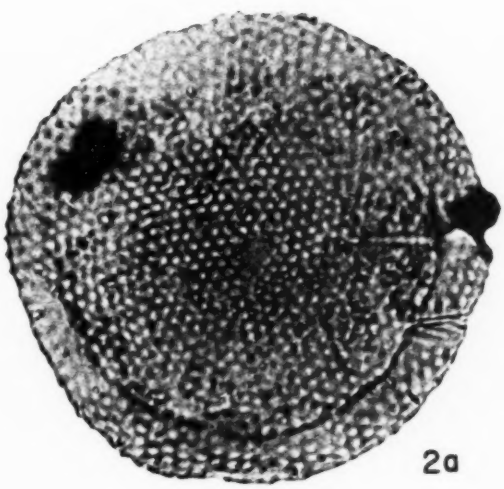
1a



1b



1c



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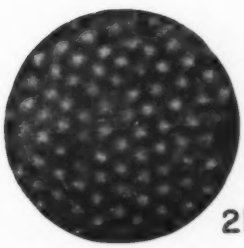
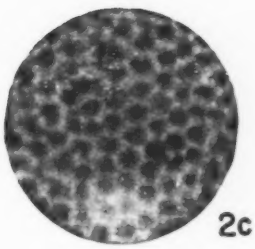


2b



2c

Norem, California Tertiary microfossils

however, are characterized by poorly defined concentric bands in the wall, instead of by hexagonal units.

*Name derivation.*—The generic name is derived from the Greek *tytthos*, small, and *diskos*, disk.

TYTTHODISCUS CALIFORNIENSIS Norem, n. sp.
Plate 68, figs. 1a–c

*Description.*—Surface generally smooth. Wall segments provided with central tubule usually less than 1 micron in diameter. Size range from 80 to 200 microns in diameter with wall thickness ranging from a twentieth to a tenth of total diameter.

*Geologic age.*—The stratigraphic range of the species extends from the Pliocene Etchegoin formation through the Miocene and Oligocene into the Eocene Kreyenhagen formation at the type locality in the Wasco oil field located 5 miles west of Wasco, California.

*Holotype.*—U. S. National Museum, 40633.

TYTTHODISCUS CHONDROTUS Norem, n. sp.
Plate 68, figs. 2a-c

*Description.*—Surface granulate. Granules closely packed, arranged in triangular pattern and on larger specimens, 2 microns in diameter. Tubules, if present, below, extending into or through granules. Size ranges from 25 to 140 microns. Wall thickness about a tenth of total diameter.

*Geologic age.*—The species is found in the Freeman-Jewett and Vedder members of the Miocene Temblor formation near Wasco, California, the type locality.

*Holotype.*—U. S. National Museum, 40632.

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 4, PP. 696–710, 12 TEXT-FIGS., JULY 1955

# PALEONTOLOGICAL NOTES

## *DORFOPTERUS*, A NEW GENUS OF EURYPTERIDA FROM THE DEVONIAN OF WYOMING

ERIK N. KJELLESVIG-WAERING
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The Lower Devonian fish bed at Beartooth Butte, Wyoming, has produced a rich fauna of fishes and eurypterids. The fishes have been described by Bryant (1934, 1935) and the eurypterids by Ruedemann (1934, 1935) and Kjellesvig-Waering and Størmer (1952). The eurypterids are not common and form only a small percentage of the fossils found. All, however, are interesting and unusual. The dolomitic limestones are considered by their discoverer, Dr. Erling Dorf (1934), as representing deposits in a fresh- or brackish-water channel or Lower Devonian age.

The Eurypterida of Beartooth Butte, along with *Pterygotus montanensis* Ruedemann from Montana, represent the westernmost occurrence of Eurypterida in North America. Three genera, each represented by a single species, have been described from the Beartooth Butte bed. To this list we can add another form, based on a telson, which has been referred to the Stylonuridae. This form is completely different from any other known eurypterid, and although represented only by the telson, merits description as a new genus. The telson in Eurypterida is considered as one of the more diagnostic parts of the morphology.

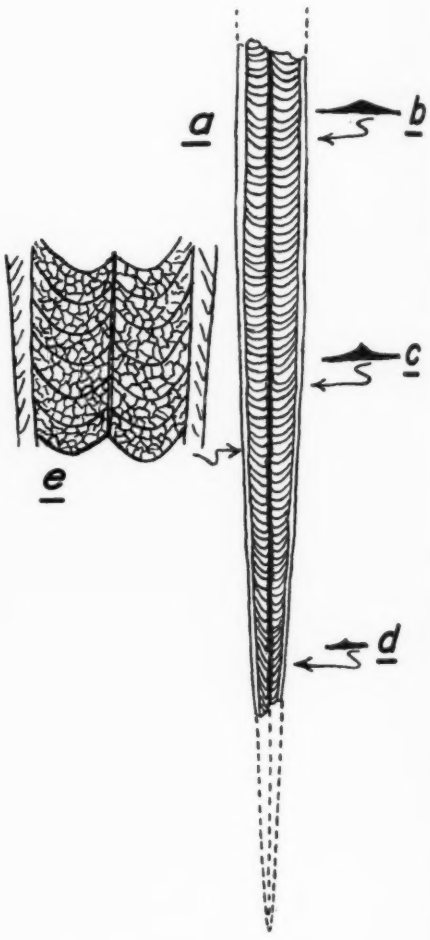
The known list of Eurypterida at Beartooth Butte, Wyoming, is as follows:

*Dorfopterus angusticollis*, n. sp.
*Eurypterus latus* Ruedemann
*Pterygotus howelli* Kjellesvig-Waering and Størmer
*Strobilopterus princetonii* (Ruedemann)

Family STYLONURIDAE Diener
Genus DORFOPTERUS Kjellesvig-Waering, n. gen.

Stylonuridae of medium size; telson, very narrow and long, spike-like, slightly carinated with evenly-spaced curved rib-like ornamentation on each side and a reticulated pattern in between rib-like ornamentation. Type species: *Dorfopterus angusticollis* Kjellesvig-Waering.

The long, narrow telson suggests the Stylonuridae but differs greatly from other genera of that family in the very peculiar ornamentation. No other eurypterid has this type of ornamentation. The genus has been named in honor of Dr. Erling Dorf of




TEXT-FIG. 1—Telson of *Dorfopterus angusticollis*, ×¾.

Princeton University, who discovered the Lower Devonian fish-eurypterid beds at Beartooth Butte.

DORFOPTERUS ANGUSTICOLLIS Kjellesvig-Waering, n. sp.
Text-figures 1, 2

The holotype, and only known specimen, comprises most of an uncrushed, dorsal impression of a well preserved telson on dolomitic limestone. The base and distal parts of the telson are missing.

The telson has a slight carina (Text-fig. 1b-1d) through the length of the structure; lateral margins converge to a point. The carinated central part is thickest and slopes gradually to the lateral margins. The telson is bordered by a flattened rim, obliquely striated and with traces of pointed scales. On each side of the carina are evenly spaced, raised, rib-like lines, each of which is opposed and is curved backward. The curving increases progressively to produce oblique lines at the distal part of the telson. In between the curved ribbing is a reticulated pattern of very fine, raised lines, much less prominent than the ribbing (Text-fig. 1e).

TEXT-FIG. 2—Holotype of *Dorfopterus angusticollis*, ×⅔.

The part of the telson preserved measures 126 mm. in length, 13 mm. in greatest width at the anterior part, and 11 mm. at midsection. The overall reconstructed length probably was about 180 mm.

*Horizon and locality.*—Associated with land plants, ostracoderms, sharks, arthrodires (Bryant 1934, p. 111) and eurypterids in dolomitic limestone of Lower Devonian age, at Beartooth Butte, Wyoming.

*Depository.*—Paleontological Museum, Princeton University.

*Remarks.*—Comparison with other eurypterids is superfluous as the peculiar ornamentation and great length of the telson is sufficient for identification.

The writer wishes to thank Dr. B. F. Howell for the loan of the holotype and Dr. G. Arthur Cooper for his kind assistance in the preparation of this paper.

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# *TYRRHENOCYTHERE*, A NEW RECENT OSTRACODE GENUS FROM THE MEDITERRANEAN

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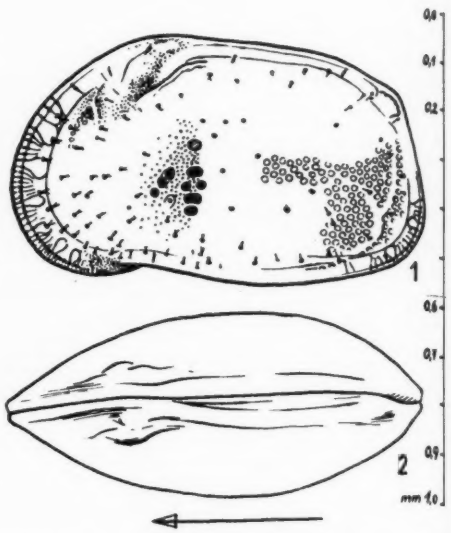
Some time ago, Dr. A. Pignatti sent me a sample of sand from the beach at Forte dei Marmi, Tuscany, Italy. This sample was rich in Ostracoda, among which was found a new species, also representing a new genus, *Tyrrhenocythere pignattii*, n. gen., n. sp. The new genus here proposed is closely allied to *Hemicythere* Sars, but is easily distinguishable from it and also from the similiar *Heterocythereis* Elofson (which, from a paleontologic point of view, is not a distinct genus) by the peculiar aspect of the marginal areas (see Text-fig. 3–5).

The specimens illustrated in the present paper are deposited in the author's personal collection (O.C.R.), now in the Museum of Geology and Paleontology at the University of Bologna. A paratype of the new species has also been deposited in the collections of the Department of Micropaleontology, American Museum of Natural History, New York (A.M.N.H.).




TEXT-FIGS. *1, 2*—*Tyrrhenocythere pignattii* Ruggieri, n. sp. *1*, Holotype, exterior of left valve (male?); O.C.R., slide no. 279/1. *2*, Paratype, carapace (male?) dorsal view; O.C.R., slide no. 279/2.

Family TRACHYLEBERIDAE Sylvester-Bradley

Subfamily HEMICYTHERINAE Puri

Genus TYRRHENOCYTHERE Ruggieri, n. gen.

*Type species* (monotypic).—*Tyrrhenocythere pignattii* Ruggieri, n. sp.

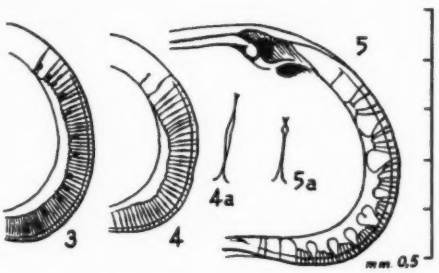
*Diagnosis.*—Carapace almond-shaped, not very thick; valves usually unequal in size, the left being a little higher than the right. Hinge of the right valve with a knob-like anterior tooth, and a broad postjacent socket, which continues into a straight groove terminating in a strong, more or less kidney-shaped tooth, which is crenated on the dorsal side, at the posterior cardinal angle. Hinge of the left valve with an anterior socket, a strong median bar thickened anteriorly and below into a strong knob-like tooth, and a posterior socket, dorsally crenated and opening toward the interior. Anterior marginal area moderately broad; inner margin and line of concrescence do not coincide because of the presence of a peculiar vestibule which is divided into a number of rounded sockets, each one terminating in a series of radial pore canals which are nearly straight, slender, and with a bulbous distal dilation. Muscle-scar pattern consisting of a vertical row of five scars, with three additional scars anteriorly.

*Discussion.*—The differences between the new genus and *Hemicythere* Sars, 1925 (type species: *Cythere villosa* Sars), and *Heterocythereis* Elofson, 1941 (type species: *Cythere albomaculata* Baird), lie only in the marginal areas, as shown in Text-figures 3–5. All specimens of *Hemicythere villosa* examined by the writer exhibit a well developed vestibule, contrasting with Puri's (1953, p. 174) description of *Hemicythere:* "Inner margin and line of concrescence coincide."

TYRRHENOCYTHERE PIGNATTII Ruggieri, n. sp.

Text-figures 1, 2, 5, 5a

*Diagnosis.*—Carapace of medium size, somewhat compressed laterally. Two forms




TEXT-FIGS. *3–5—3, Heterocythereis albomaculata* (Baird); anterior marginal area of a left valve; Recent, Rimini, Italy; O.C.R., slide no. 49. *4, 4a, Hemicythere villosa* (Sars); left valve, anterior marginal area; Recent, Dog's Bay, Ireland; O.C.R., slide no. 50; and a single radial pore canal of the same. *5, 5a, Tyrrhenocythere pignattii* Ruggieri, n. sp.; holotype, left valve, anterior half; and a single radial pore canal of the same.

are present, longer (males?) and shorter (females?); the longer form has a less protruding posterior lobe and is also more compressed laterally. In lateral view, trapezoidal-subovate; dorsal margin nearly straight, ventral margin slightly concave near the middle; anterior end broadly rounded below, posterior extremity slightly protruding as a blunt caudal lobe. Entire surface covered with dense, rounded, faintly marked punctations; and the anterior, posterior, and ventral areas are also obscurely and irregularly reticulated. The shell is usually translucent throughout, but in some specimens it is opaque in the central area.

*Dimensions.*—Holotype, a left valve (male?) (O.C.R., slide no. 279/1): length 0.85 mm.; height 0.50 mm. Paratype, a carapace (male?) (O.C.R., slide no. 279/2): length 0.86 mm.; height 0.49 mm.; breadth 0.38 mm. Unfigured paratype, a carapace (female?) (O.C.R., slide no. 279/3): length 0.79 mm.; height 0.49 mm.; breadth 0.4 mm. Another unfigured paratype, a left valve (A.M.N.H., slide no. OT-167): length 0.76 mm.; height 0.48 mm.

*Type locality.*—Tyrrhenian Sea at Forte dei Marmi, Tuscany, Italy. Rare.

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## A NEW DEVONIAN SPECIES OF *DICTYONEMA* FROM OKLAHOMA

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Kozlowski (1948, pp. 17–79) of Poland discovered the presence of a stolonal system and bilateral symmetry in the periderm of certain Dendroidea, which he compared closely with those structures in *Rhabdopleura* of the Hemicorda. Due to the finding of these two structures in dendroid graptolites by Kozlowski, authors of two new texts in invertebrate paleontology have changed the classification of graptolites from the Coelenterata to the Hemicorda. Shrock and Twenhofel (1953, pp. 736–767) place graptolites under the Hemichorda and have devoted a large part of 15 pages to the use of Kozlowski's figures. Fischer (*in* Moore, Lalicker, and Fischer, 1952, pp. 715–732) compares graptolites with Pterobranchs and in classification (p. 718) places them under Hemichordata.

Rudolf Ruedemann (1908) described and illustrated eleven Devonian graptolites from United States and two from Canada. Later (1939) he described and illustrated thirteen species, one of which was not a graptolite but consisted of ornate fragments from the margin of the cephalon of an acidaspid trilobite. Still later (1947) he described and illustrated ten Devonian species of *Dictyonema*, one of *Ptiograptus*, three of *Desmograptus*, and two of *Chaunograptus*. O. M. B. Bulman (1938) listed and illustrated a *Ptiograptus* from the Devonian

of Kentucky. The writer (1941) described and illustrated *Dictyonema delicatissima*, *D. sollarsi* and, *Chaunograptus gonothecatus* from the Haragan at the famous White Mound fossil collecting locality 4.5 miles southeast of Daugherty, Oklahoma. E. Maillieux (1942) described a Devonian dendroid graptolite from Belgium. Ferdinand Prantl (1949) described and illustrated two species of *Dendrograptus* from the Devonian of Bohemia.

In the Arbuckle Mountains, the Haragan varies in thickness from 0 to 166 feet. Generally it is a nonindurated shale or marl in which two or three thin limestones occur locally at various levels. In the eastern part of the mountains, the upper part of the formation has been altered to an indurated dolomitic limestone. In this dolomitic phase a student found a unique graptolite and gave it to Richard Alexander who was leading a field party. The locality is 16 miles southeast of Ada and 1.5 miles southeast of Fittstown, Oklahoma (NE¼, sec. 12, T1N, R6E).

The graptolites were formerly placed in the Coelenterata by Twenhofel and Shrock (1935). Because of the work of Kozlowski (1948), as noted above, some authors have changed the classification, placing them in the Hemicordata next to the vertebrates on the evidence of the two structures found in graptolites by Kozlowski, without noting the differences between graptolites and the typical Hemicordata. The two structures in graptolites stated to be similar to those in *Rhabdopleura* of the Hemichordata are a stolonal canal and a bilateral symmetry of the periderm. However, important differences exist:

1. The tiny tapering structure, the sicula, is characteristic of all graptolites. (Bulman, 1938, pp. D27, D28). A sicula does not occur in *Rhabdopleura*.
2. Bithecae representing the male element are present in Dendroidea (Bulman, 1938, pp. D4, D5, figs. 6, 7, 8) but absent in *Rhabdopleura*.
3. Gonothecae representing the female element are common in Cambrian dendroid graptolites (Decker, 1945, pl. 5, fig. 1; pl. 7, fig. 2; pl. 9, figs. 7–9; pl. 10, figs. 2, 4, 5, 17, 18), and they are highly developed in a Mississippian *Dictyonema* from South Dakota (Decker 1954). These are absent in *Rhabdopleura*.
4. Nematothecae, or stinging cells, are abundant in dendroid graptolites and absent in *Rhabdopleura*. They were first noted by the writer in 1945 on Cambrian dendroid graptolites from Texas and recently on the new *Dictyonema* (1954) from South Dakota. Now the writer is finding them in abundance on the Cambrian dendroids of Virginia and Tennessee. Gonothecae and nematothecae in graptolites had functions similar to those of hydrozoan gonangia and nematocysts.
5. The branching of many dendroid graptolites is similar to that of the Hydrozoa.
6. Graptolites lack all evidence of the presence of gill slits and a rudimentary notochord. It is the presence of one or both of these structures (Parker and Haswell, 1947) that places the Pterobranchia under the Hemicordata.

Accordingly, graptolites should be kept separate under Graptolithina, clearly unrelated to the vertebrates.

The trivial name *alexanderi* is given because of the excellent work of Richard Alexander in differentiating the Silurian and Devonian faunas in the eastern part of the Arbuckle Mountains.

### SYSTEMATIC DESCRIPTION

Class GRAPTOLITHINA Bronn, 1846, emend. Lapworth, 1875
Order DENDROIDEA Nicholson, 1872
FAMILY DENDROGRAPTIDAE Roemer, 1897
Genus DICTYONEMA Hall, 1891
DICTYONEMA ALEXANDERI Decker, n. sp.
Text-figures 1–3

The colony was about 16.6 mm. high and about 13 mm. wide at the top. The curvature of the two segments shown in Text-figure 1 indicates that the colony was infundibuliform, with a space between the segments from which the stipes have been exfoliated. Fourteen stipes occur in a space of 10 mm., and the are .5 mm. to .75 mm. wide. Dissepiments are thin but widen next to the margin of the stipes. In most cases the meshes are nearly quadrangular, and they are about 1.5 mm. wide and 3 mm. long. The thecae are cone-shaped and five occur in about 10 mm. (Text-fig. 2). The gonothecae are much larger, and are indicated by the larger arrows in Text-figures 2 and 3. Tiny nematothecae which extend slightly above the surface are shown by the smaller arrows. A bitheca occurs at the right of the large gonotheca in Text-figure 3. Bithecae are thought to represent the male element,

1

2

3

TEXT-FIG. *1*—A large and a small segment of a funnel-shaped colony of *Dictyonema alexanderi* ×2.7, showing stipes, dissepiments, and quadrangular meshes.

TEXT-FIG. *2*—Part of colony enlarged, ×24, with large arrows pointing to four gonothecae. Thecae are shown in right branch above bifurcation of stipes. Small arrows point to nematothecae.

TEXT-FIG. *3*—Part of one stipe enlarged, ×75, with large arrow pointing to a gonotheca, and smaller arrows pointing to nematothecae extending above the surface of the stipe. Apertures of others are flush with the surface. Thecae with bithecae adjacent occur above and below the gonotheca.

gonothecae the female, and nematothecae stinging cells.

This *Dictyonema* differs greatly from the two described earlier from the Haragan, being much coarser than *D. delicatissima* and having wider dissepiments. It has more regular narrower stipes than the type of *D. sollarski* in which only the lower part of the colony is preserved. Only two of those described by Ruedemann (1947) from the Devonian are infundibuliform, and this species has more angular meshes than either of them.

*Occurrence.*—Lower Devonian Haragan formation.

*Repository.*—Mus. Invert. Paleontology, Oklahoma University. Holotype, No. 30 (new system of numbering).

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# THE STRATIGRAPHICAL IMPLICATION OF THE ACCELERATED TEMPO OF EVOLUTION IN THE MESOZOIC-CENOZOIC TRANSITION OF EGYPT

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## INTRODUCTION

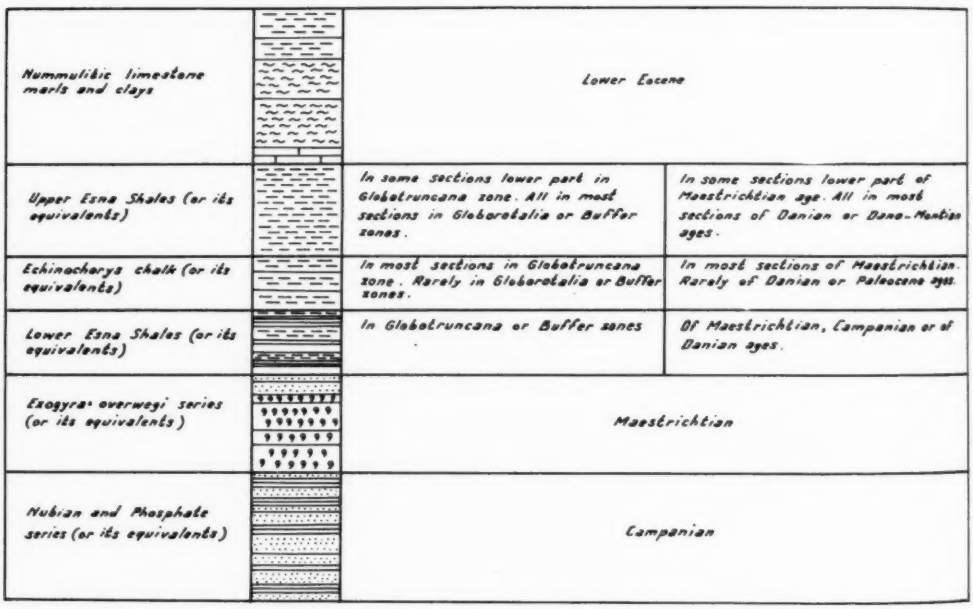
The fauna (Foraminifera) of the Mesozoic-Cenozoic transition of Egypt is very striking because of the rapid rate of evolution and the many variational changes that occur within this stratigraphic interval. This paper includes some conspicuous examples illustrating this accelerated evolution and its biostratigraphic significance.

This rapid evolution is probably a reflection of the unstable environment at the transition of these two great eras. This transition is expressed lithologically by the alternations of massive chalk, bedded chalk, Esna shales (marls, sandy limestones and clays) and limestones, indicating rhythmic oscillations of the Egyptian area. An understanding of the phylogenetic relations was possible only after the examination of a large number of specimens of species occurring in stratigraphic sequence at several localities.

## STRATIGRAPHY

In 1951, the author established three broad biozones in the Mesozoic-Cenozoic transition of Egypt using two members of the family Globorotaliidae: a *Globotruncana* zone, of Campanian-Maestrichtian age; a *Globorotalia* zone, of Dano-Paleocene age; and a Buffer zone of Danian age which separates these two zones (Text-fig. 1).

*Globigerinidae to Globorotaliidae.*—The Buffer zone is distinguished by the complete absence or extreme scarcity of both Globorotaliae and Globotruncanae, but it contains a rich globigerine fauna. The various species of this globigerine fauna make their first


Nummulitic limestone marls and clays
Lower Eocene
Upper Esna Shales (or its equivalents)
In some sections lower part in Globotruncana zone. All in most sections in Globorotalia or Buffer zones.
In some sections lower part of Maestrichtian age. All in most sections of Danian or Dano-Montian ages.
Echinocorys chalk (or its equivalents)
In most sections in Globotruncana zone. Rarely in Globorotalia or Buffer zones.
In most sections of Maestrichtian. Rarely of Danian or Paleocene age.
Lower Esna Shales (or its equivalents)
In Globotruncana or Buffer zones
Of Maestrichtian, Campanian or of Danian ages.
Exogyra overwegi series (or its equivalents)
Maestrichtian
Nubian and Phosphate series (or its equivalents)
Campanian

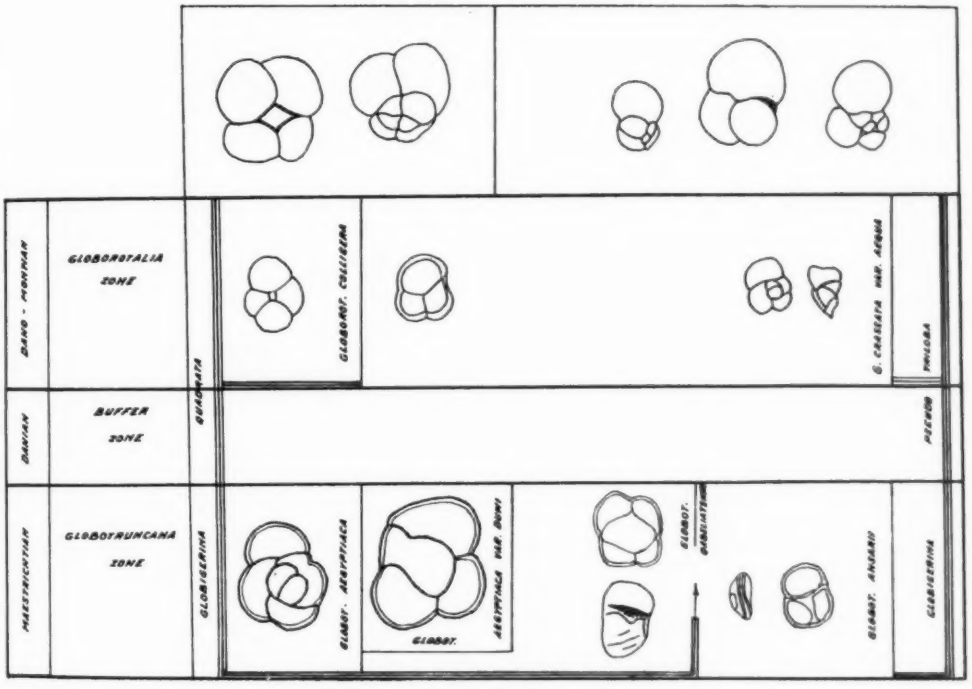
TEXT-FIG. 1—Stratigraphic sequence of Eocene-Cretaceous beds in Egypt, with their corresponding biozones and equivalent European stages. Local variation alters vertical extent of biozones.

appearance in the *Globotruncana* zone, or probably earlier. They extend more or less into the Dano-Montian, and evolve into various *Globotruncana* species in the *Globotruncana* zone, and into very similar *Globorotalia* species in the *Globorotalia* zone. The similarity between the *Globigerina* parent and each of its two decendents, Globotruncanae and Globorotaliae, or transition forms, is very striking. In many cases one finds for a certain species of *Globotruncana* in the *Globotruncana* zone, a similar *Globorotalia* in the *Globorotalia* zone but with the distinguishing globorotalid characters (Text-fig. 2).

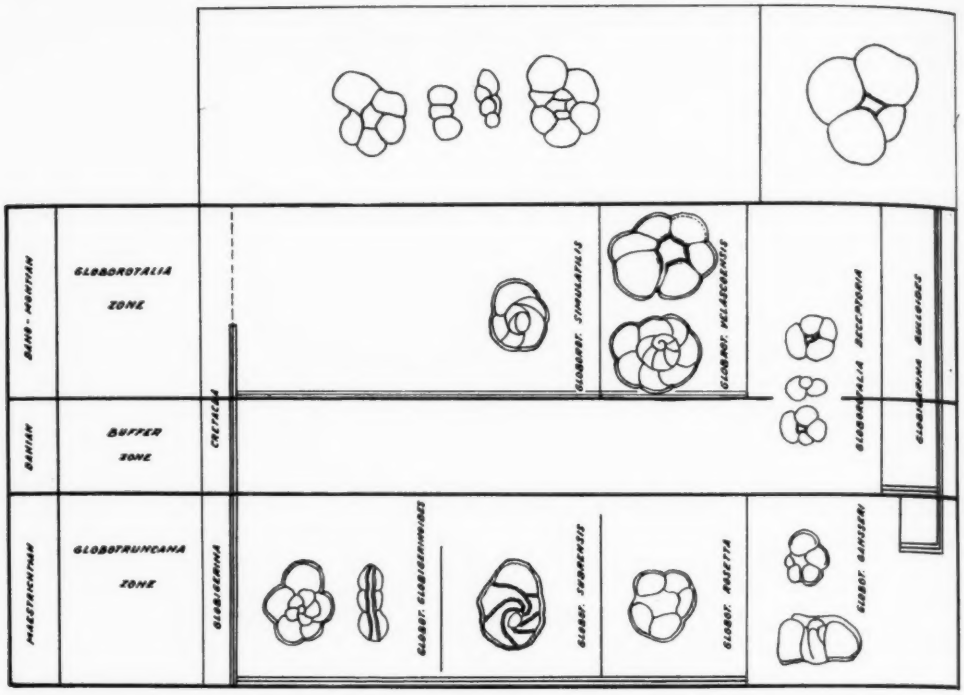
*Globigerinidae to Hantkeninidae.—Schackoina senoniensis* (Thalmann) occurs abundantly in the *Globotruncana* zone at Abu Durba, western Sinai. This species evolved by the development of a tubular spine in each of the chambers of the last whorl of *Globigerina cretacea* d'Orb., which appeared earlier in the stratigraphic sequence.

Cibicides *to* Anomalina.—*Cibicides abdurbensis* Nakkady, which appears early in the *Globotruncana* zone, evolved to *Anomalina pseudoacuta* Nakkady, a form making its first appearance later in the sequence. This change from *Cibidices* to the very similar *Anomalina* was brought about by the biconvexity and the involution of the test, the closure of the dorsal slit of the aperture and the decrease in prominence of the dorsal boss. Although both species start early in the Campanian, the *Cibicides* species is more or less confined to the *Globotruncana* zone, being rare in the basal samples of the *Globorotalia* zone. The *Anomalina* form floods the middle layers of the *Globorotalia* zone and survives to the upper beds.

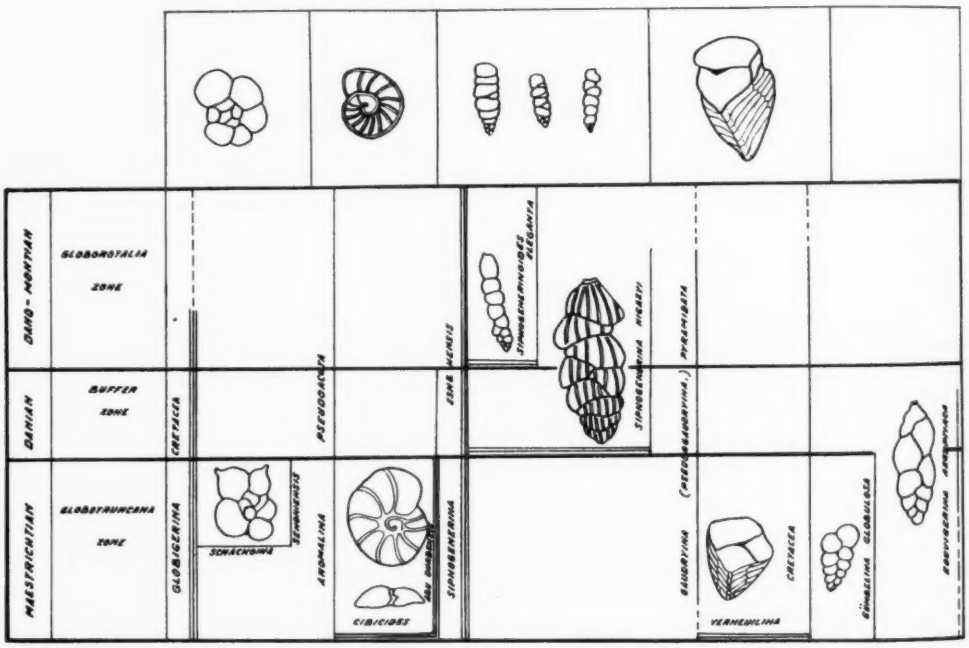
*Buliminidae to Heterohelicidae.—Siphogenerina esnehensis* Nakkady first appears in the middle of the *Globotruncana* zone but is very abundant higher in the section (*Globorotalia* zone) where it evolves to *Siphogenerinoides eleganta* (Plummer), known to be a Paleocene marker in America. This change from *Siphogenerina* to *Siphogenerinoides* is the final outcome of the evolu-




TEXT-FIG. 2




TEXT-FIG. 3



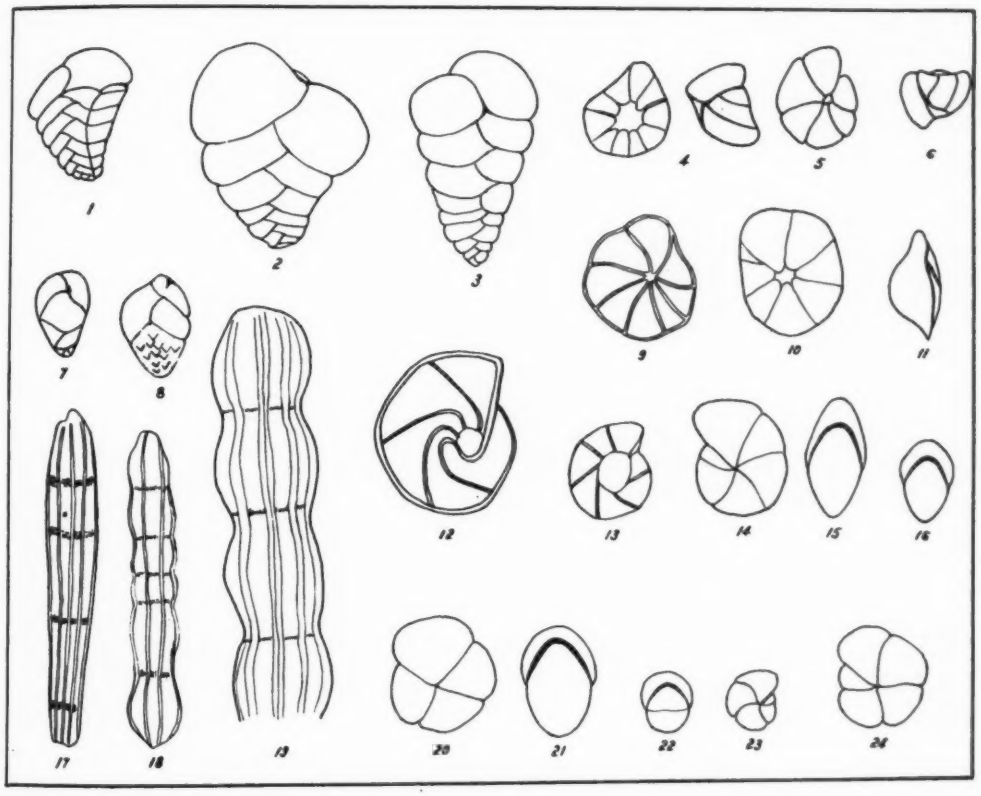

TEXT-FIG. 4

tion through successive stages in the stratigraphic sequence tending toward the formation of a smooth test with a very short triserial stage and an elongate uniserial portion with closely set nodosarian chambers.

Siphogenerina esnehensis *to* Siphogenerina higazyi *Nakkady.*—Another line of evolution of *Siphogenerina esnehensis* Nakkady is the formation of longitudinal costae on the wall of the test, which in the beginning are present on only a small portion of the test, but which later gradually cover all the chambers. The result is the emergence of a new species, *Siphogenerina higazyi* Nakkady.

Verneuilina cretacea *Karrer to* Gaudryina pyramidata *Cushman.*—*Gaudryina* (*Pseudogaudryina*) *pyramidata* Cushman developed from *Verneuilina cretacea* Karrer through the change from triserial to biserial during growth of the later ontogenetic stages. Although *V. cretacea* appears earlier in stratigraphic sequence, both species have more or less the same frequency and vertical range.

Eouvigerina aegyptiaca *Nakkady and* Gümbelina globulosa (*Ehr.*).—Both these species must have developed from a common ancestor, as they appeared almost simultaneously in the first beds (Campanian) of the *Globotruncana* zone. *Gümbelina globulosa* floods the samples from the base to the top of the zone, but the *Eouvigerina* form is rare until the uppermost layers of the Chalk or




TEXT-FIG. 5—1, *Gaudryina pyramidata* Cushman; 2, *G. laevigata* Franke; 3, *G. rugosa* d'Orbigny; 4, *Gyroidina girardana* (Reuss); 5, 6, *G. nitida* (Reuss); 7, *Bulimina murchisoniana* d'Orbigny; 8, *B. spinata* Cushman & Campbell; 9, *Eponides candidula* (Schwager); 10, 11, *E. lotus* (Schwager); 12, *Robulus chambersi* Garrett; 13, *R. isidis* (Schwager); 14, 15, *Pullenia quinqueloba* (Reuss); 16, *P. cretacea* Cushman; 17, *Nodosaria vertebralis* (Batsch); 18, *N. affinis* Reuss; 19, *N. zippei* Reuss; 20, 21, *Pullenia quaternaria* (Reuss); 22, 23, *P. reussi* Cushman & Todd; 24, *P. cretacea* Cushman.

the basal layers of the Esna shales (in other words, the top beds of the *Globotruncana* zone) where it is abundant.

The seven examples noted above were chosen particularly to illustrate the stratigraphic implication of the accelerated tempo of evolution. There are, however, other cases of rapid evolution in the Mesozoic-Cenozoic transition, which appear to have no such stratigraphic importance. The most striking examples of these are:

1. Group of *Gaudryina pyramidata-laevigata-rugosa*:
   The change progressed from *pyramidata* to *laevigata* and then to *rugosa* chiefly by the periphery and angles becoming rounded and convex instead of concave and sharp; the later portion of the test changed from pyramidal to almost quadrangular in *laevigata* and almost conical in *rugosa*.
2. *Robulus isidis* (Schwager) to *R. chambersi* Garrett:
   The change continued from *isidis* to *chambersi* by the sutures becoming distinctly raised and tangential, curving sharply near the umbo, and the body of the test becoming stouter.
3. Group *Nodosaria vertebralis-affinis-zippei:*
   The change came in the above order, through the gradual inflation of the chambers and the sutures becoming higher and more plate-like.
4. *Bulimina murchisoniana* to *B. spinata:*
   Cushman and Campbell's species *spinata* evolved from d'Orbigny's *murchisoniana* through the development of surface ornamentation.
5. *Eponides lotus* (Schwager) to *Eponides candidula* (Schwager):
   The change came about by compression of the test, the development of the keel and additional chambers.
6. *Gyroidina girardana* (Reuss) to *Gyroidina nitida* (Reuss):
   There is no doubt that there is a strong relationship between *nitida* and *girardana*, and gradation has been frequently observed.
7. Evolutionary changes within the pullenias are very striking; different species have developed one from the other through increasing roundness of the test and inflation and increase in number of the chambers. Thus *Pullenia reussi* Cushman and Todd is an evolutionary form of *Pullenia quaternaria* (Reuss), and *Pullenia cretacea* Cushman developed from *P. quinqueloba* (Reuss) almost in the same manner and through the increase in the number of the chambers.

Accelerated variational changes, affecting numbers of chambers, ratio of length and width, ornamentation, etc., could also be observed within every species in the material of the Mesozoic-Cenozoic transition. In quite a number of cases these rapid variational changes were not only fluctuating, but became constant in a sufficient number of specimens (from different samples) so that it was possible to raise such forms to the rank of definite varieties.

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EDITOR'S NOTE: The reader is also referred to LEROY, L. W., 1953, Biostratigraphy of the Maqfi section, Egypt: Geol. Soc. Amer., Mem. 54, pp. 1–70, pls. 1–13.

# PROTISTA: NON-PLANTS, NON-ANIMALS?

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## INTRODUCTION

The idea of an organic kingdom separate from and antecedent to both plants and animals is not new. For a century at least the difficulty of drawing a clear-cut line between "true" plants and "true" animals has been recognized (Owen, 1855, pp. 1–8), and proposals have been made from time to time to solve this difficulty by the creation of another kingdom. This idea is attractive from some points of view and such a group, commonly termed Protista, has been mentioned in several publications but generally it has been accorded only limited or informal acceptance.

Comparison of various published views respecting the composition of a protistid kingdom reveals little uniformity of opinion, and the very great difficulties inherent in its delineation are apparent when consideration is given to the groups that have been variously included or excluded. These are principally the bacteria and blue-green algae on one side, which are considered by some to constitute a fourth organic kingdom, and the higher algae, fungi, and sponges on the other. This situation seems to indicate rather clearly that such a kingdom, grouped around the more advanced single-celled organisms, is primarily a device designed to avoid an embarrassing difficulty inherent in taxonomy rather than an expression of a real need to associate related organisms in another major group.

## THE THIRD KINGDOM

Earlier proposals of a third organic kingdom (Owen, 1859, Hogg, 1860, p. 223; Haekel, 1866, p. xx, pl. 1) can be passed over without comment as they are only interesting historically. Recent proposals by Copeland (1938, 1947) and by Moore (1954) draw upon modern biologic knowledge and purport to set up a "natural" kingdom whose consistency warrants recognition. The basic distinguishing characters of the third kingdom, however, are viewed quite differently by these last two authors. Copeland cites nuclear structure and details of mitosis, whereas Moore relies upon the "acellular" character of the concerned organisms. In neither case have these features in themselves furnished a compelling reason for the separation of a third kingdom. They are, rather, presented as substantiating evidence that a group desired for other practical reasons should be accepted as logical and "natural."

Under these circumstances, the validity of reasoning and significance of arguments favoring the recognition of a third kingdom should be scrutinized carefully. This is particularly evident when differences in emphasis and differences in limits of the kingdom as conceived by Copeland and by Moore are noted. Copeland excludes the schizophytes with the remark: "The most profound of all distinctions among organisms is that which separates those without nuclei from those which posses them" (1947, p. 342), but Moore includes schizophytes and states: "Actually, the distinction between Monera [=schizophytes] and Protoctista [=third kingdom of Copeland] hardly justifies assignment of them to separate kingdoms. . . ." Also Copeland excludes the green algae, which he considers "valid plants" (1938, p. 412; 1947, p. 353) and sponges, although the latter were first excluded doubtfully (1938, p. 415). Moore includes the green algae (1954, p. 594) and excludes sponges without comment. It is quite evident, therefore, that considerable discrepancies exist in the proposed composition of a third kingdom and consequently the "natural" character of its boundaries is seen to be a matter of opinion.

## THE PROBLEM

The distinction between plants and animals, that once seemed so obvious, has faded with advance in biologic knowledge. For more than a century no one has succeeded in framing satisfactory mutually exclusive definitions, and it now seems evident that no sharp division can be made between the

two conventional organic kingdoms. The troublesome organisms that are now recognized as combining both plant and animal characteristics are some of the flagellates and the slime-molds, and their removal from the botanical and zoological systems invites consideration. Such action, however, would not resolve the plant-animal problem but only narrow it. Also it would produce new and unconvincing boundaries.

If this problem of an indeterminate plant-animal boundary is of such importance that decisive action must be taken, there seems to be no alternative but to segregate the organisms in question into a separate kingdom. They are so closely related to other unicellular and "acellular" organisms of definite plant and animal types, however, that many of these latter must be carried into the third kingdom also. Thus, this solution seems to demand a major taxonomic change and the exclusion of most thalophytes and protozoans, and perhaps the sponges, from the plant and animal kingdoms.

Nature recognizes no sharp and absolute divisions, and taxonomy is a man-made system fitted to natural patterns in whatever way is considered to be most meaningful and convenient. This system is subject to revision, and it has been altered and improved repeatedly. In spite of progressive perfection, however, the limitation of coequal groups at any taxonomic level and the arrangement of groups into a hierarchy are certain to be imperfect and arbitrary to some degree. Nontypical and intermediate forms that do not fit neatly into the compartments of the taxonomist are bothersome but must be expected to occur. The problem which they pose is a common one, and each case requires judgment involving both theory and practice. New groups believed to be important can be, and often are, created for the reception of such strays, but these groups raise new artificial boundaries and commonly create new problems or magnify the importance of old ones. In the end some sacrifice of theory to practice is demanded because if all such problems are to be solved by the creation of new groups there is almost no limit to the taxonomic fragmentation that may be expected.

The recognition of a third, or protistid, kingdom, however it may be defined, primarily involves a change in the emphasis accorded to certain taxonomic boundaries. It adds nothing to biologic knowledge either as regards the nature of the organisms themselves or their phylogenetic relationships. Therefore, it should be judged solely on the basis of (1) its convenience, (2) its implications regarding taxonomic philosophy and (3) the practical consequences of the resulting change in compartmentalization.

### CONVENIENCE

(1a) The recognition of a protistid kingdom conveniently eliminates the necessity of separating the lower plants and animals.

Such action is likely to find favor with specialists in some of the lower groups (Moore, 1954, p. 596) because these persons are more closely concerned with the plant-animal problem than are others. For this same reason, however, the specialists are less likely to take an objective view of the taxonomic system as a whole and may be expected to grant greater importance to this problem than others believe it deserves.

(1b) The recognition of a protistid kingdom removes the questionable organisms from the jurisdiction of both botanists and zoologists and thus assures uniformity in nomenclature and may promote uniformity in classification, which has not been achieved by botanists and zoologists working independently.

These same desirable results may be accomplished by agreement, and the last is not a strong argument for a third kingdom. There is no certainty, however, that uniformity in classification would be attained—compare the classifications of Copeland and of Moore which are commented upon below.

### PHILOSOPHIC CONSIDERATIONS

(2a) The recognition of a protistid kingdom implies that the distinction between these organisms and plants and animals, as restricted, is more significant than the distinction between plants and animals, as commonly recognized.

The differentiation of coequal taxonomic groups should be based upon increasingly fundamental criteria as one goes upward in the taxonomic scale. Phyla are generally

considered to consist of large groups of plants or animals that differ importantly in their grades of organization, anatomical construction, and modes of reproduction. Distinction between the conventional plant and animal kingdoms is of a higher grade based on fundamental differences in biochemistry and physiology, which paved the way toward adaptation to two quite different ways of life and resulted in the development of strikingly different functional and structural systems. There seems to be no question but that the differences between plants and animals, as commonly defined, are much more important morphologically and much more significant biologically than the differences between protistids and either plants or animals, as restricted. The boundaries based on the latter differences generally have been considered to separate phyla or lesser groups, and in most respects these differences are of no greater importance than those which distinguish major phyla. Consequently, the recognition of a protistid kingdom obscures the most fundamental of all distinctions in the organic world and at the same time greatly increases the emphasis placed on other less significant distinctions.

(2b) The recognition of a protistid kingdom substitutes a "horizontal" type of classification for a "vertical" one.

A "horizontal" classification is often convenient because it unites organisms in a similar stage of development and makes definition of a group simpler and recognition of its members easier. It is generally considered, however, to be less "natural" than a "vertical" classification, which unites genetically related organisms and separates different evolutionary lines. There may be convincing practical reasons for preferring certain "horizontal" groups to "vertical" ones, if the nature and relationships of the concerned organisms are doubtful. Much better reasons should be required, however, for changing a firmly established "vertical" system to a "horizontal" one, and most biologists are likely to consider such a change as retrogression.

### PRACTICAL CONSIDERATIONS

(3a) The recognition of a protistid kingdom, as its most obvious result, necessitates restriction and redefinition of the plant and animal kingdoms.

By definition, a protistid kingdom creates a group of non-plants and non-animals which includes a multitude of well known organisms recognized as plants and animals for more than a century, and the declaration that these are neither plants nor animals contravenes long standing and firmly established concepts that have proved to be both significant and useful. No matters of fact are involved, for both concepts only reflect opinions regarding classification. It does not appear to be advisable, however, to discard an old firmly established system without reasons that appeal to a majority of biologists as compulsive.

(3b) The recognition of a protistid kingdom does not eliminate the overlapping of botanical and zoological interests in the border line plant-animals.

Botanists and zoologists will continue to concern themselves with protistid organisms because these constitute an essential base for the consideration of evolution and phylogenetic relationships in both branches of the organic world.

(3c) The recognition of a protistid kingdom does not solve the problem of intermediate forms.

The typical unicellular protistids are joined to both typical multicellular plants and typical multicellular animals by intermediate forms, and two hazy and arbitrary boundaries are substituted for one. This problem is less apparent on the zoological than on the botanical side, where numerous transitional forms lead to the higher algae. Sponges occupy a comparable position on the zoological side, however, and they were included in the protistid kingdom by early taxonomists. The statement that "The multicellular algae retain acellular fundamental characteristics" (Moore, 1954, p. 592) is almost equally applicable to sponges. The inclusion or exclusion of sponges and various groups of algae points up the most noteworthy differences in a protistid kingdom as outlined by its proponents.

(3d) The recognition of a protistid kingdom encourages the recognition of one or more other non-plant, non-animal kingdoms.

Moore includes the bacteria and blue-

green algae as a sub-kingdom of the Protista (1954, p. 594), but other modern taxonomists (Copeland, 1947, p. 350; Grassé, 1952, p. 39) have separated them as another independent kingdom. Regardless of whether or not this distinction is recognized, where will the still more lowly bacteriophages and other viruses find a place in the organic system?

(3e) The recognition of a protistid kingdom encourages, if it does not necessitate, the creation of subordinate phyla.

Only two phyla, Protophyta and Protozoa might be recognized (Grassé, 1952, p. 39), but this offers no advantage over the conventional system. The great diversity exhibited by protistids is sure to tempt taxonomists to subdivide them into more numerous groups so as to make them comparable to the other kingdoms. All such groups are not distinct. Many of them are connected by intermediate forms, and many are of uncertain relative value. Of the 9 phyla proposed by Copeland (1947, pp. 350–359) and the 14 recognized by Moore (1954, p. 594), only 3 seem to correspond. Four of Copeland's phyla are included as subordinate groups in one phylum of Moore and four of Moore's phyla are included in one of Copeland's. A recent standard zoological work states: "The Protozoa are exceedingly difficult to classify because of the many transitional types and forms of uncertain relationships. It is impossible to erect exclusive definitions, and consequently the definitions center about typical members" (Hyman, 1940, p. 46). These remarks are equally applicable to protophytes. Few if any of the proposed phyla are separated by differences comparable to the differences that divide the higher phyla of plants and animals.

(3f) The recognition of a protistid kingdom necessitates the drafting of another code of international rules to govern its nomenclature.

Moore (1954, p. 593) has considered this matter in some detail and offers a group of excellent suggestions. A third code, however, is almost certain to complicate still further already complex nomenclatural procedures.

## CONCLUSIONS

The recognition of a protistid kingdom conceals more nearly than it solves an old taxonomic problem. In accomplishing this, it shifts emphasis from what appear to be more important to less important distinctions, substitutes "horizontal" for "vertical" classification, requires somewhat artificial restrictions of the plant and animal kingdoms, provides two arbitrary interkingdom boundaries instead of one, fails to eliminate overlapping botanical and zoological interests, encourages the recognition of additional kingdoms and a considerable number of ill-defined phyla, and necessitates the drafting of a third code of nomenclatural rules. These considerations indicate that the convenient solution of one problem, accomplished by the recognition of a protistid kingdom, is more than balanced by the disadvantages and additional problems resulting from this action.

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# NOMENCLATURAL NOTE

## *ELLIOTTELLA*, NEW NAME FOR *PSILONOTUS* STEHLI

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Graham F. Elliott has kindly called to my attention the fact that the name *Psilonotus*, which I applied to a brachiopod (Stehli, 1954, Bull. Amer. Mus. Hist., vol. 105, p. 323), is preoccupied by the hymenopteran genus, *Psilonotus* Walker, 1834 (Entom. Mag., vol. 2, p. 179). I therefore propose the name *Elliottella* as a replacement for *Psilonotus* Stehli, 1954 (*non* Walker, 1834). The type species remains the same, *P. transversalis* Stehli, 1954.

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# REVIEWS

**DIE FORAMINIFEREN DER OCEANIC-FORMATION (EOCAEN-OLIGOCAEN) VON BARBADOS, KL. ANTILLEN,** By Jean Pierre Beckmann. Eclogae Geologicae Helvetiae, vol. 46, no. 2, 1953 [published May 30, 1954], pp. 301–412, 29 text-figures, 15 plates and 1 chart. E. Birkhäuser, Basel, Switzerland.

The paleontological study of the Oceanic formation had up to the present time been restricted to the Radiolaria, which were covered by Haeckel's classical work of 1875. A systematic, stratigraphic, and ecologic study of the rich foraminiferal fauna had long been desirable. This gap has now been closed by Beckmann's thesis on the Foraminifera of the Oceanic formation (Eocene-Oligocene) of Barbados, Lesser Antilles.

Besides the extensive systematic description and figuring of the foraminiferal fauna, which includes 236 species and varieties (2 species and 1 variety are new), the author gives special attention to an estimate of the depth of deposition of the Foraminifera- and Radiolaria-rich sediments of the Oceanic formation. This is a problem which has been much disputed in the past. In his approach Beckmann assumes that the depth distribution of the benthonic foraminiferal genera and species still living in Recent seas has not changed since Oceanic time. After a careful study of the bathymetric records of Recent descendants of the genera found in the Oceanic formation, he arrives at an approximate depth of deposition of 1000–1500 meters.

In the Oceanic formation, Radiolaria and Foraminifera occur in the same beds. For the former the depth of deposition in Recent and fossil sediments is generally considered to be far greater than Beckmann's estimation. There are good indications, however, that favorable conditions for Radiolaria can also exist in shallower waters. Under certain circumstances—Beckmann mentions such factors as cool currents, supply of $SiO_2$ by volcanic activity, etc.—even the Oceanic beds containing Radiolaria might well have been laid down at the moderate depth suggested by the benthonic Foraminifera.

The studied material originates from three sections (the Mt. Hillaby, Bath, and Consets sections) which were collected by A. Senn. The uppermost Middle Eocene to Lower Oligocene age of the Oceanic formation was determined by comparison with Eocene and Oligocene Foraminifera from other Caribbean areas and from Central and South America. Close faunistic relations were especially noted with the Eocene Navet and Oligocene Cipero formations of Trinidad, which probably were laid down under similar conditions. The lower Mt. Hillaby beds of Barbados compare well with the middle-upper part of the Navet formation of Trinidad and the upper Mt. Hillaby beds are likely to be an age equivalent of the Hospital Hill marl of Trinidad. The Bath beds are in the reviewer's opinion comparable with an as yet undescribed zone immediately underlying the Oligocene Cipero *Globigerina ciperoensis* zone (formerly *Globigerina* cf. *G. concinna*) of Trinidad; whereas the Codrington College beds correlate with Trinidad's *Globigerina ciperoensis* zone.

The absence of such foraminiferal species as *Hantkenina bermudezi*, *H. primitiva*, and *Globorotalia cocoaensis*, which are characteristic of the uppermost Eocene Mt. Moriah beds of Trinidad, leads the reviewer to believe that these beds and possibly the basal part of the Cipero formation are not represented in the discussed sections of the Oceanic formation of Barbados. Such a hiatus, suggested by the absence of the above-mentioned pelagic species, together with certain typical Upper Eocene benthonic Foraminifera such as *Bulimina jacksonensis*, might however be filled in by layers of radiolarian marl and volcanic ash which are especially common near the Eocene-Oligocene boundary. The ecologic conditions persisting during the deposition of these beds might have excluded the forms mentioned. It would be of interest to investigate this problem further, and the reviewer feels confident that results would be obtained by a minute comparison of the rich pelagic faunas of the Oceanic formation with those of Trinidad, where a very close biostratigraphic zonation could be established with them.

Beckmann's thesis is a valuable contribution to our knowledge of the micro-

paleontology, stratigraphy and ecology of the Oceanic formation of Barbados. Furthermore, it is, with its study of the bathymetric distribution of benthonic Foraminifera and its implications to the depth of deposition of the investigated beds, a paper of more than local interest. The author is to be commended on this extensive and well illustrated study.

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*English summary of:* CONTRIBUTION À L'ÉTUDE DES FORAMINIFÈRES DES EAUX SAUMÂTRES; ETANGS DE CANET ET DE SALSES: by Jean and Yolande Le Calvez, 1951, Vie et Milieu, tome 2, fasc. 2, pp. 237–254.

Foraminifera are almost exclusively marine organisms. They are known however to occur in littoral waters and in brackish inland waters.

Littoral brackish waters are characterized by low salinities and also by large (seasonal or daily) fluctuations of temperature. In estuaries, the action of tides plays a very important role as well as the inflow of fresh water from streams. In such an environment Foraminifera are generally represented by euryhaline calcareous or arenaceous species. The fauna has few species but many individuals; their size is small; the wall, thin, translucent and without ornamentation. The origin of these populations is easily explained since there is a permanent relationship with sea water.

Brackish-water Foraminifera were mentioned for the first time by Brady in a paper on Foraminifera and Ostracoda of tidal rivers. This work was published in 1870 in collaboration with Stewardson and Robertson. Not until 1922 were brackish-water Foraminifera mentioned again when Hofker published a study of the Protozoa from the Zuiderzee in Holland. In 1931 Dolgopolskaja and Pauli gave the following list of Foraminifera collected near the biological station of Karadagh in the Black Sea, where the waters show a low temperature and low salinity: *Ammobaculites agglutinans, Verneuilina scabra, Quinqueloculina seminulum, Massilina secans, Nonion stelligerum, Elphidium poeyanum, Elphidium crispum, Elphidium advenum* var. *pontica, Elphidium incertum, Rotalia beccarii, Discorbis vilardeboana* var. *karadajica.*

Hedberg in 1934 studied the Foraminifera from the brackish waters of Maracaibo Strait, Venezuela, and reaches the conclusion that *Rotalia beccarii, Haplophragmoides, Ammobaculites, Trochammina,* and *Quinqueloculina fusca* are essentially brackish-water forms. P. Marie's study of the Foraminifera of the Rance River estuary in Normandy followed in 1938; he gave a detailed list and remarked about the scarcity of arenaceous forms and the abundance of *Rotalia beccarii* and representatives of the Miliolidae and *Elphidium.* In the same year Bartenstein and Brand described *Jadammina,* a "new" genus, living and fossil, characteristic of brackish waters. Brand continued the study and found that *Nonion, Elphidium, Rotalia* (*R. beccarii*), and *Jadammina* are present in brackish waters, and he gave the abundance of these forms versus the salinity of the water. His results show that *Nonion depressulum* is the most resistant calcareous foraminifer, and that *Trochammina* and *Jadammina* are the most euryhaline arenaceous species. The successive predominance of these two groups of Foraminifera—first calcareous, then arenaceous—would indicate with certainty the progression of a brackish-water facies. More recently (1948) Cushman and Bronnimann described in a preliminary note a few new brackish-water species from Trinidad, without any ecologic comment.

Foraminifera, sometimes living, have been found in inland brackish waters, hundreds of miles away from any ocean. The only characteristic common to these environments, otherwise entirely different, is the presence of chlorides which brings about salinity conditions very similar to littoral brackish waters. This, however, does not explain the origin of these faunas, for Foraminifera do not have durable spores and it is impossible to imagine transportation by birds or fishes. Is it the remnant of a fauna living at the time when the sea covered these regions? Are Foraminifera able to migrate by underground waters? The different writers who found Foraminifera in true continental waters have not been able to explain their origin, and it is

hoped that future research will give the answer to this problem.

Until 1883 the existence of Foraminifera in inland waters was not known. At that time Daday discovered in some salt ponds of Transylvania a small chitino-arenaceous form which he called *Entzia*. In 1928 *Spiroloculina*, *Lagena*, *Nodosaria*, *Textularia*, and *Cornuspira* were mentioned by Brodsky in a list of Foraminifera from the Kara-Kum Desert.

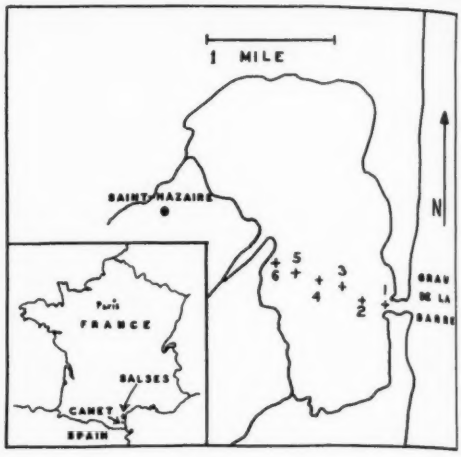
Then in 1935 Gauthier-Lievre discovered that Foraminifera live in the Saharian waters of the Rhir River. Samples were collected at stations scattered over a distance of 100 kilometers. She found that *Ammodiscus*, Miliolidae, and *Trochammina* are common, whereas *Nonion*, *Anomalina*, and *Cibicides* are scarce. She considers this fauna as a remnant from the time when the sea covered the region. In 1936 Hada studied the Foraminifera from brackish-water lakes in Japan. Bartenstein in 1939 mentioned *Haplophragmoides canariensis* in brackish inland waters in Germany and could not explain the presence of this form living in waters more than 300 kilometers away from an ocean.

In France the ponds bordering the Mediterranean coast offer an ideal site to study brackish-water Foraminifera. The Canet Pond and the Salses Pond were chosen for this purpose.

## CANET POND

The Canet Pond has an area of 2500 acres; it is separated from the Mediterranean Sea by a sand bar of variable width. Intermittently it is in communication with the sea by a channel called "Grau de la barre." Fresh water from a little stream flows in the pond almost all year. The pond is in the process of being filled; its depth, usually less than 0.8 meter, reaches 1.7 meters in winter. The salinity of the water varies a great deal due to inflows of fresh water and important evaporation in summer time. As an example the salinity was 70°/₀₀ (about twice that of the Ocean) in some parts of the pond during the summer of 1950.

Bottom samples were collected at six stations (Text-fig. 1). The muds, when washed and sieved, were found to contain Foraminifera. The most important data are summarized in the following table (A




TEXT-FIG. 1—Schematic map of Canet Pond. Adapted from J. and Y. Le Calve.

= abundant, C common, R rare, VR very rare, and 0 none).

In order to evaluate the variation in size of the individuals from one border of the pond to the other, approximately 40 individuals of *Rotalia* were measured at each station. The average diameters are the following:

Station 1 = 369 microns
Station 2 = 365 microns
Station 3 = 326 microns
Station 5 = 284 microns

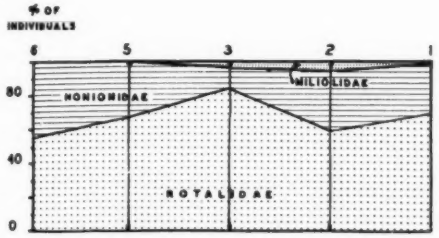
The extreme rarity of *Nonion pompilioides*, encountered only at stations 1 and 2, suggests that the individuals of this species have been brought from the open sea during a period of communication, but that they have not been able to survive in this new environment. It is also noticeable that the Miliolidae, which have a very low frequency in the eastern half of the pond, disappear entirely in the western half (Text-fig. 2).

The measurements of the Rotaliidae seem to indicate that the median size of the individuals increases regularly from the land toward the sea. There is also an increase of salinity in the same direction, indicating a possible trend.

The nature of the bottom seems to have the greatest influence on the vitality of the species and their power of reproduction. For example, sample No. 4, collected ap-

TABLE 1

| STATION NUMBER | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Depth in meters | 0.80 | 0.90 | 1.00 | 0.90 | 0.75 | 0.90 |
| Salinity in parts per 1000 | 23.82 | 23.69 | 23.37 | 23.37 | 23.37 | 23.37 |
| Total Number of Foraminifera | 418 | 1,038 | 126 | 0 | 256 | 94 |
| % of Rotaliidae | 67.45 | 58.75 | 84.15 | 0 | 67.20 | 55.30 |
| % of Nonionidae | 30.15 | 35.00 | 11.10 | 0 | 32.80 | 44.70 |
| % of Miliolidae | 2.40 | 6.25 | 4.75 | 0 | 0 | 0 |
| CHARACTER OF THE BOTTOM | black mud | sandy mud | black mud | putrid mud | yellow mud | grey mud |
| *Rotalia beccarii* | C | A | C | C | R | C |
| *Rotalia beccarii* var. *tepida* | C | A | C | C | C | R |
| *Nonion depressulum* | R | C | R | C | R | R |
| *Nonion pompilioides* | R | R | 0 | 0 | 0 | 0 |
| *Elphidium excavatum* | R | R | VR | 0 | VR | VR |
| *Elphidium littorale* | R | C | R | 0 | R | R |
| *Quinqueloculina costata* | VR | C | R | 0 | 0 | 0 |

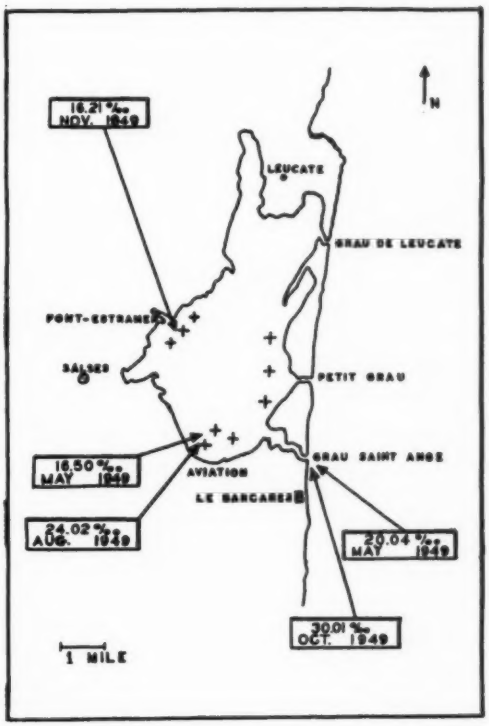



TEXT-FIG. 2—Percentage distribution of families in Canet Pond. From data by J. and Y. Le Calvez.

proximately in the center of the pond in a putrid mud, does not contain Foraminifera; of the two stations, No. 3 and No. 5, station No. 3 is closer to the sea but contains far fewer Foraminifera (see table of data and text-fig. 1).

## SALSES POND

Salses Pond is located a few miles north of Canet Pond; it has an area of 20,000 acres; as in the case of Canet Pond it is separated from the sea by a sand bar. Three channels allow communication with the open sea during storms or in winter time. During the summer the waters of the pond are completely isolated from the sea. The depth of the water varies in different places; there are also some seasonal variations due to evaporation. Salinity changes are caused by the inflow of fresh water from a few streams and also by evaporation (Text-fig. 3).




TEXT-FIG. 3—Location of stations in Salses Pond. Some salinities are given as examples. From data by J. and Y. Le Calvez.

Three series of stations were made near the following localities: Font-Estramer, Aviation, and Petit-Grau. The results being similar for the different stations of the same series, only one station will be considered. The data are tabulated below:

TABLE 2

| LOCALITIES | Font-Estramer | Aviation | Petit-Grau |
|---|---|---|---|
| Depth in meters | ? | 0.80 | 0.80 |
| Total number of Foraminifera | 464 | 2,540 | 4,070 |
| % of Rotaliidae | 92.25 | 89.75 | 81 |
| % of Nonionidae | 7.75 | 10.25 | 17.50 |
| % of Miliolidae | 0 | (2 individuals) | 1.5 |
| CHARACTER OF THE BOTTOM | mud | sandy mud | sandy |
| *Rotalia beccarii* | R | C | A |
| *Rotalia beccarii* var. *tepida* | C | C | A |
| *Nonion depressulum* | R | R | C |
| *Elphidium excavatum* | VR | VR | R |
| *Elphidium littorale* | R | R | C |
| *Quinqueloculina costata* | O | O | R |

The same procedure was used to investigate the variation of size of Foraminifera from one border of the pond to the other. Diameter measurements were made on 40 individuals of the two families, Rotaliidae and Nonionidae. The results are the following:

| | *Rotalia* | *Nonion* |
|---|---|---|
| Petit-Grau | 359 microns | 323 microns |
| Aviation | 349 microns | 311 microns |
| Pont-estramer | 302 microns | 288 microns |

In the Salses Pond the range of salinity variation is less than in the Canet Pond. *Nonion pompilioides* does not occur and the Miliolidae are restricted to the eastern border of the pond.

The bottom is more homogeneous in character than in the Canet Pond, and there is a progressive transition from sand to sandy mud and mud on the western border. The nature of the bottom seems to regulate the reproduction of Foraminifera. They are ten times as abundant on the sandy bottom as compared with the muddy western border. The size of the individuals decreases in the same direction as the salinity. This is valid for the Rotaliidae and the Nonionidae.

## DESCRIPTIVE STUDY OF THE COLLECTED FORAMINIFERA

The fauna is composed exclusively of calcareous forms. The number of individuals per sample is large, but only seven different species and three families are represented. The number of atypical specimens within one species may be very important; however, there does not seem to be any relation with the location in the pond.

What is most noticeable is the thinning of the test and the reduction of the ornamentation; this is especially true for *Rotalia beccarii* var. *tepida*, in which the granulations of the umbilical region are smaller and sometimes disappear entirely. Among the species of *Quinqueloculina* the chambers are often very irregular, the costae disappear, and the general aspect of the individuals is quite abnormal.

All the species comprising this fauna live also in the open ocean at shallow depth, except *Elphidium littorale* ["new" species] which seems to be limited to the ponds.

## GENERAL CONCLUSIONS

The fauna encountered in the two ponds is characterized by the few species adapted to the environment and also by the abundance of individuals. *Rotalia beccarii* is by far the most abundant, a fact which confirms the brackish habitat of this species.

The character of the bottom seems to

regulate the vitality and power of reproduction, whereas the variation in salinity appears to affect the size of the test.

ROBERT E. ARNAL
Western Gulf Oil Co., Los Angeles

ÉTUDE GÉOLOGIQUE DES BASSINS MIO-PLIOCÈNES DU NORD-EST DE LA TUNISIE (RÉGION ENTRE MATEUR, FERRYVILLE ET PORTO-FARINA), by P. F. Burollet, Annales des Mines et de la Géologie, No. 7, Tunis, 1951, 94 pp., 11 figs., 1 photographic pl., 2 pls. (geol. map and sections, both 1:50,000).

An oil seepage at Aïn Smara focused geological interest on this region and made a thorough survey of it desirable. The results are presented in the text and in a geologic map 1:50,000, supplemented by a series of geologic sections and several detail maps, both stratigraphic and structural.

Eliminating details of purely oil-geological interest, the author puts the stratigraphic emphasis on the Miocene and Pliocene beds, the earlier (Triassic to Eocene) formations having been thoroughly discussed in the previous literature.

Within the Miocene, are recognized the lower Miocene ("1st cycle"), the Vindobonian ("2nd cycle"), and the continental Pontian; and within the Pliocene the marls of Raf-Raf and the sandstones of Porto-Farina are distinguished. In an appendix, the Pleistocene is considered; its lower portion is assigned to the Villafranchian, and the marine and old dune formations are referred to the middle or upper Pleistocene.

Faunal lists of both mega- and microfossils are added to the descriptions of the several stratigraphic members.

The paleogeography and the rather complex structure of the area are treated in the two concluding chapters.

The bibliography comprises 31 papers and 6 geologic maps.

OTTO HAAS
American Museum of Natural History

LES AMMONITES PYRITEUSES DU TITHONIQUE SUPÉRIEUR ET DU BERRIASIEN DE TUNISIE CENTRALE, by Mme. S. Arnould-Saget. Annales des Mines et de la Géologie, No. 10, Tunis, 1953, iv+132 pp., 1 map, 61 text-figs., 1 table, 11 pls.

This important monograph deals with an assemblage of pyritized ammonites, studied first in 1937 by M. Breistroffer. They are from marls, about 100 m. thick and transitional in age from the upper Tithonian to the Berriasian, of central Tunisia.

Most of the ammonites studied are referred to Roman's family "Palaehoplitidae" which is, however, invalid, lacking a type genus. This family, the Berriasellidae Spath, is represented by 43 species of *Himalayites*, one of them new; 28 of *Berriasella*, three of them new; 4 of *Neocosmoceras* (one? new); 3 of *Dalmasiceras;* and 3 of *Neocomites*. Next in abundance is the family Olcostephanidae, represented by 8 species of *Proniceras*, two of them new, and 9 of *Spiticeras*, one of them new. Other ammonite families are much less abundant in this assemblage, namely, the Phylloceratidae with 3 species; the Lytoceratidae with one species of *Protetragonites;* the Haploceratidae with two species of *Haploceras* and one of *Pseudolissoceras;* the Aspidoceratidae and the Desmoceratidae with a single species each, referred to *Aspidoceras* and to *Neolissoceras*, respectively; and the Bochianitidae Spath (=Protancyloceratidae Breistroffer) with 3 species of *Bochianites*, one of them new, and 6 of *Protancyloceras*, all of them new. In addition, a single hercoglossid, *Pseudonautilus geinitzi* (Oppel), is recorded.

Precise figures indicating the abundance of species are not given. On the whole, the author seems to deal with individuals rather than with populations.

The paper is accompanied by 12 plates with excellent full-tone reproduction, and these are supplemented by 61 text-figures, most of them suture drawings.

Correlation with 12 contemporaneous ammonite assemblages (2 from Algeria, 4 from France, and one each from Andalusia, Moravia, Crimea, India, Argentina, and Mexico) is shown in a chart and carefully discussed. However, no attempt is made at an investigation of paleoecological conditions of pyritized ammonite faunas, repeatedly discussed by the Termiers (1951, 1954), Rutten (1954), Goguel (1954), and in the reviewer's forthcoming revision of the Mount Hermon ammonites.

OTTO HAAS
American Museum of Natural History

NONMARINE LOWER PLIOCENE SEDIMENTS OF CALIFORNIA, A GEOCHRONOLOGIC-STRATIGRAPHIC CLASSIFICATION, by Donald E. Savage. Univ. Calif. Publ. Geol. Sci., vol. 31, no. 1, 1955; 26 pp., 13 text-figs.; $0.35 (paper cover).

Dr. Savage presents the first comprehensive treatment of the California "Mio-Pliocene problem" from the viewpoint of vertebrate paleontology and stratigraphy. We can hope that this is only the first of a series of papers of its kind on the important role of nonmarine stratigraphy in the entire Tertiary history of western America.

The study begins with a discussion of the prevailing inconsistencies that have resulted from the general failure to distinguish between the concepts involving lithic and geochronological ideas, and from differing assumptions and interpretations regarding Lyellian series relationships. By comparison of the attributes of Tertiary mammalian, invertebrate, and plant distribution in space and time, an excellent case is made for the validity of vertebrate paleontology as a basis for interregional Cenozoic geochronology. Moreover, parts of California lie in a particularly apt region in this respect because of the common association of marine and nonmarine strata.

Following a brief but generally critical review of the concept of *stage* in stratigraphy, Dr. Savage defines and exemplifies the *Cerrotejonian* and *Montediablan* (mammalian) stages as subdivisions of the recognizable California equivalent of the lower and upper Clarendonian "provincial age" of Wood *et al.* (1941), respectively. Although the boundary separating these two stages is primarily defined on a biostratigraphic basis, the integrated physical stratigraphy should help to establish its acceptance as one of essential chronostratigraphic nature. The lower limit of the Cerrotejonian stage and the upper limit of the Montediablan stage, however, do not appear to be defined as yet on a similar basis. These limits, of course, must await similar treatment of the preceding and succeeding stratigraphic record.

In the reviewer's opinion, the most important contributions of this first-rate paper are (1) the clarity with which the author points out the "disparate geochronologies from the various paleontological [and geological] disciplines," and (2) his exemplification of the kind of approach that should ultimately lead to geochronologies that are time-stratigraphic in concept as well as name, and to scales that are not "out of phase," so that a given succession may no longer be referred consistently to the "Miocene" on the basis of its invertebrate fauna and to the "Pliocene" on the vertebrate evidence.

HARRY E. WHEELER
University of Washington

MISCELLANEOUS REPORTS OF THE RESEARCH INSTITUTE FOR NATURAL RESOURCES, numbers 27–33, 1952–1954. The Research Institute for Natural Resources (Shigen Kagaku Kenkyusyo), Tokyo, Japan.

The numbers of this periodical here reviewed were issued between September, 1952, and March, 1954, on a quarterly basis. The texts of the articles are largely in Japanese, but some are in English, French, or German. Most, but not all of the papers with Japanese texts have a summary, often tantalizingly brief, in one of the Western languages, usually English. The illustrations are line drawings or halftones. Each number is paged separately. All titles are given in one of the Western languages or transliterated into English on the back page of the cover of each number.

These seven numbers contain 93 papers, totaling 775 pages. Nine papers are of direct interest to paleontologists, whereas an additional 33 are geological in character. A "Table of Contents in all Publications Hitherto Issued by the Res. Inst. Natur. Resources" is attached as a 25 page supplement to No. 33 (March, 1954). It indicates that the Journal started in 1943. Until 1950 all titles, except for names of organisms or chemical compounds, are in Japanese.

A series of five papers by K. Oyama ["On the Mixture of Fossil Communities at Atebi, Chiba Prefecture," No. 28, pp. 35–41, Dec. 1952; "Palaeoecological Studies on the Littorinidae," No. 30, pp. 26–33, June 1953; "On the Fossil Communities of the Coastal

Water (No. 1)," No. 31, pp. 54–58, Sept. 1953; "Fossil Communities of the Oceanic Waters," No. 32, pp. 23–30, Dec. 1953; "On the Fossil Communities of the Coastal Waters (No. 2)," No. 33, pp. 92–98, March 1954] appear to be of considerable importance to the paleoecologist. Unfortunately the texts of all five articles are in Japanese, and the English summaries are inadequate for a full understanding of the papers. In the four papers on fossil communities, Oyama points out the importance of various types of oceanic and coastal water masses to paleoecology, and then he analyzes the faunas of selected Cenozoic formations, noting the modern habitat of the various species, and gives his conclusions as to the environment in which the fossils and containing sediments were deposited. Provided the data on distribution and habitat of the living organisms is adequate, this type of analysis can be extremely fruitful, although insofar as can be determined by inspection of his text (the reviewer regrets lack of knowledge of the Japanese language), Oyama has not considered the relative abundance of the various fossil species. The author explains several incongruous elements in the fossil faunas as having been transported by currents or hermit crabs. It would be important to know the relative proportions of faunal elements of these types. In the two papers on Coastal waters he describes and discusses two faunas representing "strong" and "medium" degrees of "embayment," and one of a "gulf." In the "Oceanic" paper the fauna of a Pleistocene "Coral-bed" is analyzed and considered to consist of seven different elements varying from a "brackish water dweller" to species from an area with a "stronger" [warmer ?] Kurroshio current than in Japan at present. Additionally a fauna considered to have lived near a "solitary" [oceanic ?] island, and a fauna characterized by a mixture of Kuroshio and "coastal water" elements are discussed. The first paper of the series considers a fossil fauna containing a mixture of "euneritic," "subneritic-bathyneritic," and "Oyashio under current" elements, with the "euneritic" element containing "both eurythermal and stenothermal types of warm and cold elements." This intriguing mixture is explained as due to varying currents and/or transportation by hermit crabs. The Littorinidae paper discusses the worldwide habitat of members of the family, notes that they are poorly represented in the fossil record as compared with their present-day abundance, and then suggests that the littorinids are only preserved in embayments and that they are destroyed under "open sea" environments. Inasmuch as these gastropods are primarily intertidal and subtidal dwellers, it seems more likely that the scarcity of sediments of these environments in the geological record is a more probable explanation.

The other papers of paleontological import in the series are: Nagahama, M., "Smaller Foaminifera from the Boring Wells in the Oil Field of Western New Guinea," No. 32, pp. 58–66, Dec. 1953; Kuwano, Y., "Studies on the Recent Foraminifera from the Sea around Japan, I, Foraminiferal Thanatocenoses in the Southern Part of the Okhotsk Sea (I)," No. 32, pp. 71–83, Dec. 1953; *ibid*, ("2"), No. 33, pp. 56–67, Mar. 1954; Mawatari, S., Hirosaki, Y., and Kobayashi, S., "Settlement and Growth of Acorn Barnacle, *Balanus amphitrite communis* Darwin, I," No. 33, pp. 46–55, Mar. 1954.

In Nagahama's paper the fossil foraminifers identified in 51 samples from ten different wells in western New Guinea are recorded and conclusions as to the paleogeography and paleoecology at the time of deposition are given.

Kuwano's second paper is a continuation of the first, but unfortunately neither has a summary in a Western language. However the two papers are well supplied with charts and tables giving collecting localities, depth, percentages, and actual abundances of different types as well as individual species of foraminifers. Finally, six different "Types of assemblages" are recognized in the benthonic fauna and their geographic and bathymetric distribution shown. The information that can be gleaned from this paper without a knowledge of the language suggests that it is an important contribution.

The paper by Mawatori, Hirosaki, and Kobayashi is primarily concerned with the

fouling effects of barnacles, but it contains many useful data on the time and rate of settling of the larva and the growth rates after settlement.

The papers present in these numbers of this Journal indicate that it would be well for paleontologists, particularly those concerned with paleoecology, to examine it regularly, although the lack of a Western language text will be a drawback to many.

J. WYATT DURHAM
University of California

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 4, PP. 721–757, JULY 1955

# SOCIETY RECORDS AND ACTIVITIES

## REPORTS AND MINUTES OF THE TWENTY-NINTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The twenty-ninth annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Keystone Room of the Statler Hotel, New York, N. Y., March 28–31, 1955, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

The Presidential Address of the Society, "The Practical Value of Microfossils," was given by Hans E. Thalmann in the joint session on Tuesday, March 29.

Also in the joint session, Brooks F. Ellis presented an "Honorary Membership Scroll" to Jesse J. Galloway, the first president of the S.E.P.M. Galloway was elected to honorary membership by the Society in January, 1955.

J. J. GALLOWAY, University of Indiana, receiving S.E.P.M. honorary membership certificate from BROOKS F. ELLIS, American Museum of Natural History.

# SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

## 29th ANNUAL MEETING

## NEW YORK, N. Y.

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## PROGRAM AND ABSTRACTS

### Monday, March 28, 1:30 P.M.

### Main Ballroom, Hotel Statler

## MINERALOGY AND SEDIMENTARY PETROLOGY

*Presiding:* R. R. SHROCK, Massachusetts Institute of Technology, Cambridge, Massachusetts AND RAYMOND SIEVER, Illinois State Geological Survey, Urbana, Illinois

### 1. PENNSYLVANIAN LITHOLOGIES AND THEIR SIGNIFICANCE IN NORTHEAST NEVADA*

ROBERT H. DOTT, JR.
Humble Oil & Refining Company,
Eugene, Oregon

Pennsylvanian in north-central Nevada comprises 5000 feet of cherty limestone, quartz arenite, siltstone, and conglomerate with a major unconformity between middle and upper Pennsylvanian. In east-central Nevada, non-conglomeratic Ely limestone facies (2500–3000 feet) disconformably underlies Wolfcampian with upper Pennsylvanian missing.

Predominant limestone types are calcarenite and calcirudite, particularly crinoidal and fossil

* Published with permission of Oak Ridge Institute of Nuclear Studies.

hash (microcoquina) varieties, and some oölite. Detrital quartz impurities are characteristic. Brachiopod, fusulinal and other coquinites are common. Coquinoid limestones have sparser, little-damaged fossils. Coralline biostromes are present, but no definite bioherms. Arenites and siltstones with quartz and chert grains grade to arenaceous limestones. Conglomerates contain chert and quartzite fragments.

Fragmented fossils, detrital quartz, oölite and diastems indicate shallow water, frequent agitation, winnowing and redeposition in an unda environment. Orogeny in the eugeosyncline produced lands which shed chert and quartz detritus eastward into the miogeosyncline. Quartz was apparently swept westward from the craton. Local epirogenic upwarps and platforms within the miogeosyncline subsided less, have significant unconformities, and furnished clastics to adjacent negative areas of more continuous deposition.

Environment of deposition was no different from many epeiric seas of cratonal regions. Greater thickness is the sole significant distinction of these miogeosynclincal sediments.

## 2. SEDIMENTARY ENVIRONMENTS OF COASTAL PLAINS AND THEIR CONTINENTAL SHELVES

W. Armstrong Price

Agricultural and Mechanical College of Texas, College Station, Texas

Basic factors of coastal development are: time, energy, sediment supply, offshore bottom conditions, organisms, climate. Analysis of coastal development involves (1) usual hinterland geological and geomorphic information covering tributary drainage basins, and (2) oceanographic studies of regional wind systems, wave trains, offshore bottoms felt by waves, tidal regime, coastal currents and hydrology of major streams. Feasible numerical evaluation of basic factors is done as time and data permit. A fruitful tool used is a regional geomorphic survey. Thus, principles have been formulated and types and processes, previously incompletely understood or overlooked, described.

Using approach outlined, some 7000 miles of coastal plain on American Atlantic coasts have been typed. During successive high-sea-level periods of the Quaternary, environments have been stable and similar, with major changes in few definitive factors. Thus, each major coastal sector had no more than two major shoreline types. Most variable basic factors have been time (local rejuvenation by vertical or horizontal shoreline movement) and sediment supply (when new transporting agent and sediment supply operated).

A normal coastal plain has been consistently built out in opposition to tectonic deformation. Its contemporary and Quaternary features are dominantly progradational. Glaciated, isostatic rebound and volcanic coastal plain sectors are not considered normal. Depositional plains of offlapping, coalescing subaerial deltas of low gradient, alluvial-fan type are commonest coastal plain units. With sand excess, strand plains (shoreline terraces) formed by barrier chains ("offshore bars"), with lagoons or coastal marsh belts, develop step-like terrace series. Emerged shelf terraces (surprisingly) are rare, requiring lee coast (low to zero wave energy) free from strandplain structures and deltaic cover. Known examples are on low, karstic, limestone peninsulas.

Sand carried by longshore drift, powered by breakers, forms beach ridges, barriers and transverse bars in rivers and inlet mouths, smoothing shorelines and preventing coastal serration by tidal scour. Without such protection, transverse tidal scour produces cross-channeled coasts and funnel-shaped estuaries, maintains transverse patterns of ria coasts and develops tidal-channel networks in marshes, deltas and drowned karst archipelagoes.

Most new shoreline types described are from neglected, non-scenic coasts with low wave energy, few harbors and low economic development.

## 3. TRIASSIC REEFS OF THE DOLOMITE ALPS, NORTHERN ITALY

Norman D. Newell

American Museum of Natural History, New York, New York

Triassic reefs of the Dolomite Alps, southern Tyrol, rival the Permian reefs of West Texas in magnitude of development and exposure; hence they rank among the greatest groups of fossil reefs in the world. The principal and only really important work on the Tyrolian reefs was published seventy-five years ago by Mojsisovics who accurately described and interpreted the complex facies relationships, thus paving the way for all subsequent studies of fossil reefs.

For two weeks during the summer of 1954, the writer was able to make an inspection of some of the Tyrolian reefs with the following conclusions: The general facies relationships are remarkably similar to those of the Permian reefs in West Texas. Massive reefs grew horizontally at sea level shedding coarse reef talus into surrounding areas of stagnant (euxinic) facies. Well-bedded back-reef dolomite beds overlie and laterally replace the reefs. The reef basin boundary is irregular as compared with the margin of the Delaware basin of Texas. Apparently, many of the massifs of the Dolomites are more or less isolated reefs. Further investigation may show that some of these were separate atolls or table reefs.

## 4. RECENT STROMATOLITIC SEDIMENTS FROM SOUTH FLORIDA

Robert N. Ginsburg

Marine Laboratory, University of Miami, Coral Gables Florida

In south Florida Recent equivalents of many Precambrian and Paleozoic stromatolites occur in the shallow protected marine environment, in the open intertidal zone, and on intermittently flooded mud flats above high water. Millimeter

laminae rich in blue-green algae alternate with sediment of the same magnitude. The sediment is particulate $CaCO_3$, mostly bioclastic debris, and abundant carbonate precipitated by algal photosynthesis is not present.

Structures are related to environment:

1. Protected water 1–6 feet. Small discrete spheroid forms whose internal structure resembles common fossil types.
2. Open intertidal zone on rocky shores. Laminated sediments cover tens of square feet, irregularities of rock substratum initiate structures which are preserved by differential sediment binding by algae.
3. Intermittently flooded mud flats above low water. Laminated sediments cover hundreds of square feet; type of laminations and surface structures produced by differential deposition, algal growth, and desiccation; some structures preserved as domes and undulations.

The abundance of micro-folds, micro-unconformities, and animal burrows cross-cutting the laminations in the three types is also environmentally dependent.

Detrital texture and the influence of an adhesive film are the basic criteria for recognizing these types of stromatolites in an ancient rock. The environmental relationships of structures may be useful for paleoecologic interpretations.

## 5. BARRIER ISLAND SEDIMENTARY UNITS ALONG THE GULF COAST*

FRANCIS P. SHEPARD
Scripps Institution of Oceanography, La Jolla, California

The collection and study of several hundred samples from the barrier islands along the central Texas coast and of many samples from other portions of the Gulf coast have led to the establishment of criteria for the recognition of at least four sedimentary environments of deposition within the island margins. These include beaches, dunes, barrier flats, and inlets or channels. The sediments in each are distinctive and can ordinarily be distinguished from the sediments deposited in the bays and on the open shelf.

By use of criteria obtained from extensive studies of the Gulf coast environments, samples from 17 borings into barrier islands have been investigated. It has been found that in most of the borings the sediments are indicative of barrier island environments down to depths of 30 to 50 feet which represent the contact with the weathered clays and oxidized sands indicative of Pleistocene low-sea-level stages of deposition. To date no boring has indicated that barrier islands have grown up from the outer margin of the sand deposition (approximately 30 feet in this area) during a still stand of sea level. It seems more likely that the barrier islands started to develop with the last rise in sea level and built upward keeping pace with the rise. In some places the barrier islands have encroached over the bays, but elsewhere the beaches have grown over nearshore Gulf deposits. A surprisingly large proportion of the samples are indicative of the channels and inlets within the islands. Isolated data provided by Humble and Gulf oil companies' offshore drilling operations have indicated that barrier island deposits of considerable thickness lie below relatively thin, open Gulf sediments.

There are some reasons for believing that the barrier islands have grown in part on the top of old Pleistocene barriers so that very considerable thicknesses of sand have developed over more than one cycle. There seems to be no reason why similar sand masses should not have formed during subsidence in earlier periods and particularly during the swinging sea levels of ancient glaciations such as those of "Permo-Carboniferous."

* This investigation was supported by a grant from the American Petroleum Institute Project 51.

## 6. GRAIN ORIENTATION IN BEACH SANDS: A POSSIBLE MEANS FOR PREDICTING RESERVOIR TREND

R. H. NANZ
Shell Development Company, Houston, Texas

Long axes of the elongate sand grains on Texas and Florida beach slopes are aligned statistically normal to the beach strike, suggesting that the subsurface trend of beach deposits can be predicted from oriented core samples.

Waves refract as they approach shallow water, their fronts become subparallel to the beach trend and the swash on the beach slope creates currents statistically normal to the beach trend. Other workers have shown that the long axes of experimentally deposited sand grains are subparallel to the direction of water currents.

In the present study, long axis is rigorously defined as the line of minimum moment of inertia of a plane image of the grain. For each sample, long-axis orientations are determined for approximately 300 grains selected on a grid pattern in a polished or thin section and data are plotted in a circular histogram. A mean direction is computed by a least-squares method, spread is estimated by standard deviation, and statistical significance is evaluated by a variance-ratio test. Since the true three-dimensional fabric is planar subparallel to the bedding with a strong lineation, two-dimensional fabric analysis in the bedding plane is sufficient to define the lineation, which is approximately parallel to the current direction.

These findings apply only to beach-slope deposits. They do not necessarily give information on orientation of grains which form the major part of barrier island or self deposits.

## 7. ESTIMATION OF RECENT SEDIMENT SIZE PARAMETERS FROM A TRIANGULAR DIAGRAM

WILLIAM J. PLUMLEY* AND DONALD H. DAVIS
California Research Corporation, La Habra, California

Data from 191 size analyses of Recent sediments from several depositional environments

* Person presenting paper.

were studied to obtain relationships among sediment-size measures and sand-silt-clay composition. A simple analytical procedure exists whereby sediment-size parameters of median, mean, deviation measure, and skewness of Recent sediments may be estimated from a three-component plot of sand, silt, and clay percentages. The three-component analysis is made easily by abbreviated size analysis methods, and the size parameters are obtained graphically from the three-component plot. Conversely, if the median and deviation measure of a sediment sample are known, the composition of the sediment may be obtained in terms of percent sand, silt, and clay. Thus, a one to one correspondence exists between points on the triangular diagram and pairs of median and deviation measure values (excluding the periphery of triangle). The estimation method for obtaining sediment-size parameters will facilitate size analysis of large numbers of Recent sediment samples where semiquantiative data are desired.

## 8. COMPOSITE END MEMBERS IN FACIES MAPPING

W. C. KRUMBEIN
Northwestern University, Evanston, Illinois

Most facies maps are designed to show the approach of the stratigraphic section toward one or another of the end members used in the map design. In certain applications of facies maps it is observed that some optimum combination of end members is associated with particular environmental, tectonic, or other conditions, some of which may have practical significance in oil occurrence. A "distance function" based on transformation of trilinear to Cartesian coordinates permits selection of any point within a facies triangle as a center of optimum combination of end members, with contour lines indicating the "facies distance" of any other section from the selected point.

The distance function provides a single system of contours which serve as an evaluation map for more detailed studies of lithologic variations. The relation of the distance function to other contouring systems in facies map design is developed by several illustrations.

## 9. ANALYSIS OF SEDIMENTARY FACIES IN POTTSVILLE STRATA OF CENTRAL APPALACHIAN COAL FIELD

E. C. DAPPLES* AND R. M. MITCHUM
Northwestern University, Evanston, Illinois, and Carter Research Laboratory, Tulsa, Oklahoma

Sedimentary facies distinctions are recognized by isolation of subdivisions of Pottsville strata. In lower units quartzose, locally conglomeratic sandstones of wide areal distribution show concentration in marginal part of major sedimentary basin, and tend to be distributed in northeast-southwest alignment. Such sandstones gradually disappear as successively higher stratigraphic units are examined, and are replaced by subgraywackes. These become increasingly abundant toward thicker depositional areas and tend to show east-west orientation.

* Person presenting paper.

Repetitive cycles of basal, regionally transgressive, quartzose sandstones, overlain by a coal association and shale, characterize lower units. Upper units are typically alternations of subgraywacke sandstones, coal associations, and shale. Shales overlying the coals are distinguished as gray, plant-bearing, non-marine varieties; or dark gray, with sideritic concretions, and limestone lenses (marine). The two major shale types are intergradational.

Conditions of deposition are interpreted as follows:

1. Quartzose sandstones represent marine transgressions from northeast to southwest, with sands moved in a southwest direction. Such sandstones are the coalescence of bars along an expanding shoreline.
2. Influx of fine-grained, subgraywacke sands and silts from eastern sources to drive shorelines westward, and substitute brackish water conditions leading to coal deposition.
3. Diminution of supply of eastern clastics, and re-advance of the sea over continental deposits as subsidence continued.
4. Gradual suspension of sediment supply from northeast to cut off deposition of quartzose sands during marine invasion.
5. Substitution of dark gray, calcareous shales and thin limestones for deposition of quartzose sandstones. Such occurred when marine conditions were re-established as the eastern sediment supply dwindled, and continental deposition could not prevail over the continued subsidence.

## 10. THE APPLICATION OF A DISCRIMINANT FUNCTION TO A PROBLEM IN PETROLEUM PETROLOGY

JOHN RATHBONE EMERY
Carter Oil Company, Tulsa, Oklahoma

From a study of 32 thin sections, 16 cut from the oil-bearing Berea sandstone and 16 from the barren Pocono formation, it has been shown that it is possible, through a linear combination of measured petrographic properties, to differentiate between the Pocono and Berea populations set up in this experiment.

Geologically these formations are similar in age, stratigraphic interval and general lithology, and hence the differentiation of oil bearing from barren sediments within a formation will help in the search for petroleum reservoirs within that formation.

A detailed investigation of the 32 thin sections indicated the following generalized differences between the two populations:

1. The average quartz content of the two populations is very similar but the Pocono has a bimodal distribution while the Berea is unimodal. The majority of the Berea samples fall between the extremes shown by the Pocono.
2. The Berea is generally finer grained than the Pocono but its entire distribution falls within the Pocono limits.
3. The Berea is better sorted than the Pocono.
4. There seem to be no important differences

between the populations with respect to particle sphericity and orientation. There are differences between individual samples, but when the measurements are combined the populations are not significantly different.
5. The frequency distribution of the packing index of the Pocono samples indicates a strongly bimodal population whereas the Berea again shows a unimodal form which falls between the modes of the Pocono distribution.
6. The Berea has a higher average porosity than the Pocono.
7. The Berea has a lower average bulk density than the Pocono.

After the evaluation of some of the variables which influence the oil-bearing propensity of a rock, it is possible by use of a discriminant function to describe quantitatively the difference between oil-bearing and barren sediments within a formation. This knowledge may be used as a powerful tool in future petroleum exploration, particularly in the search for so-called "stratigraphic traps."

## 11. APPLICATIONS OF COLLOIDAL MECHANICS IN THE INTERPRETATION OF NATURAL POLYDISPERSE SYSTEMS

J. Robert Moore, III

Harvard University, Cambridge, Massachusetts

The sedimentological characteristics of extremely fine-grained particles found in the present marine environment are analyzed in the light of recent experimental and theoretical research in colloidal mechanics. Data on thermal, electrokinetic, and gravitational forces affecting dispersion and distribution are presented. Type examples of the so-called red clays and blue muds of the North Atlantic are presented to show that their present distribution patterns are more realistically interpreted by the use of colloidal mechanics applicable to the known current and thermal architecture of North Atlantic waters.

Analysis of the variations in the colloidal characteristics at the solid-liquid interface of a discrete clastic particle as it passes through thermal-salinity zones is reviewed.

A statement on the use of colloidal mechanics in the future research in marine sedimentation is given.

## 12. SEDIMENTARY PETROLOGY OF THE CRETACEOUS FORMATIONS OF NORTHERN DELAWARE IN RELATION TO PALEOGEOGRAPHIC PROBLEMS

Johan J. Groot

Delaware Geological Survey, Newark, Delaware

The purposes of the investigation of the heavy mineral content of the Cretaceous formations of northern Delaware were: (1) to establish a correlation between mineral zones and geologic formations; (2) to discover their area of provenance; (3) to interpret the mineral suites in terms of environmental conditions which must have prevailed in their source area.

Three mineral suites are found in the non-marine Cretaceous formations of northern Delaware. A staurolite suite is correlated with sediments of Patuxent age, a zircon-rutile-tourmaline suite with sediments of Patapsco-Raritan age (undifferentiated) and again a staurolite suite in the Magothy formation. The source area from which these non-marine sediments were derived is thought to be mainly the nearby Piedmont and, to a smaller degree, the adjacent folded Appalachian Mountains.

The marine Upper Cretaceous formations are characterized by an epidote suite. This suite is considered to be the result of mixing sediments from two sources; a source located to the south, and the crystalline rocks of the Piedmont and the Paleozoic sedimentary rocks of the folded Appalachian Mountains to the west.

Observations indicate that Patapsco-Raritan time was a period of intensive weathering in the source area of the non-marine Cretaceous deposits, and it is believed that during that time the Appalachian Mountain system to the west or northwest of Delaware was essentially a peneplain.

## 13. PRELIMINARY STUDY OF MINERALS FROM THE EAST GULF OF MEXICO

Nora Gladwin Fairbank

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

Bottom samples collected by *Atlantis*, research vessel of the Woods Hole Oceanographic Institution, in the eastern Gulf of Mexico, are being studied to find what minerals are present and in approximately what proportions. All samples are surface sediments, and in many the mineral or rock grains are masked in varying degrees by shells and other material of organic origin. A major difficulty is the reduction of abundant organic materials without affecting the minerals. Several different techniques have been tried in order to concentrate the minerals for study. A regular procedure is being worked out in order to arrive at results which will be comparable from one part of the area to another.

As there are over two hundred samples, a few have been chosen from each traverse for this study in order to make a reconnaissance of the distribution and zonation with relation to distance from shore and depth of water as well as with reference to continental sources. Both heavy and light minerals have been studied, and a quantitative estimate has been made of mineral distribution both geographically and by species.

## Papers To Be Read by Title

### THE STRATIGRAPHIC AND PALEOECOLOGICAL SIGNIFICANCE OF THE Sr/Ca RATIO IN SEDIMENTS AND FOSSILS

Karl K. Turekian
Lamont Geological Observatory,
Palisades, New York

Strontium is known to substitute significantly for Ca in crystal structure. The extent of the substitution in natural systems such as shells and sediments will be a reflection of the conditions of deposition. This can be demonstrated in several geologic situations such as the depositional environment of the Florena shale (Permian) and the ecology of contemporary pelagic fauna.

The possibility of Sr abundance data being useful for stratigraphic correlation is strongly limited because of the wide variations observed along the strike in several "typical" formations containing significant amounts of calcium carbonate such as the Harrodsburg limestone (Mississippian) of Indiana.

In a formation where no marked lithologic facies change has been observed over a considerable area, there are significant and consistent variations in the strontium concentrations, which in some cases correlate with the abundance and variation of faunal types.

Variations of Sr concentrations in genera of major faunal groups contemporaneously secreting identical polymorphs of calcium carbonate illustrate the so-called "vital effect."

It is postulated that the "vital effect" can be best explained as a kinetic effect rather than a selectivity on the part of the organism. That is, the speed of shell growth is reflected in the concentration of Sr in the calcium carbonate lattice.

### APPLICATION OF BUSINESS MACHINES AND ELECTRONIC COMPUTERS IN THE REDUCTION OF BOTTOM SEDIMENT DATA

Robert E. Burns and Charles G. Purves
U. S. Navy Hydrographic Office,
Washington 25, D. C.

The rapidly increasing number of bottom sediment samples and cores obtained from various Navy surveys and analyzed at the U. S. Navy Hydrographic Office has led to the development of rapid methods of data reduction. Methods are discussed of utilizing the I.B.M. punched-card system and the I.B.M. Electronic Computer 607 to reduce drastically the amount of hand computation normally required in laboratory analysis of sediments. Proposals are made for future use of these data in testing the various standard sedimentation hypotheses, as well as determining basic correlative relationships that may be present among their analyzed elements.

## PRESIDENTIAL ADDRESS

Tuesday, March 29, 9:00 A. M.
Main Ballroom, Hotel Statler

## JOINT SESSION

### THE PRACTICAL VALUE OF MICROFOSSILS

Hans E. Thalmann

A hundred years ago Christian Gottfried Ehrenberg published his monumental book *Mikrogeologie* (1854) together with an atlas of 41 plates on which he pictured practically everything which he was able to observe under the microscope. He revealed for the first time the presence and abundance of Recent and fossil microbios, plant and animal, in rocks of all ages and in samples sent to him, or collected by him, from all over the world. During fourteen years of diligent search he assembled more than 25,000 microscopic preparations and about 1000 thin sections from which he selected more than 4000 drawings (most of which were 300 times magnified) of what he then classified as microscopic Polygastrica, Polycystina, Phytolitharia, Geolithia, Polythalamia, and Zoolitharia. Ehrenberg, the father of what we now call micropaleontology, was undoubtedly the first who tried to unravel the secrets of "the invisible active organic life" on earth, and the first who gave an iconographic record of hystrichospherids, dinoflagellates, coccolithophorids, and silicoflagellates. Today we are celebrating the Centennial of Micropaleontology, in spite of the fact that d'Orbigny as far back as 1840 already stressed the stratigraphic value of one of the groups of "larger" microfossils, the Foraminifera. But even in this group of microfossils, enormous progress has only been made since the First World War, when applied micropaleontology in the exploration for oil came into existence with emphasis on the

study of Foraminifera, Ostracoda, conodonts, graptolites, and a few other groups of microfossils. The practical value of the still smaller microfossils, already known when Ehrenberg's *Mikrogeologie* appeared in print, has been recognized, however, only since the termination of the Second World War.

When discussing the new frontiers in Micropaleontology, Carey Croneis (1942) already pointed out the great potentialities for commercial application which a future and more intensive study of several groups of "micro-microfossils" offers, and he wondered why so few American paleontologists paid any attention to these minute fossils. Fortunately, the situation has now changed; micropaleontology, as we knew it during the last forty years, is undergoing a steady metamorphosis as more and more attention is paid to, and more and more monographs and papers deal with, these long forgotten, neglected, or overlooked microorganisms. Although great progress has already been made in some of these groups of microbios, we are still in the empirical and analytical state of their study, but each advance gradually leads to a synthesis and fuller understanding of the nature, systematic position, and ultimate practical value of these new tools in oil-field stratigraphy.

Let us not forget that only forty years ago, W. Deecke stated that the Ostracoda are of no stratigraphic or palecologic value whatsoever and that it is not worthwhile to bother with these otherwise very interesting microfossils. Thirty years ago, C. Diener took a similarly pessimistic view regarding the value, if any, of the Foraminifera for stratigraphic purposes. Twenty years ago, when discussing the practicability of coccoliths, radiolarians, hystrichospheroids, calpionellids, pollen and spores as indicators for age or environmental conditions with many outstanding paleontologists in this country and Europe, I was told that their minute size, ranging roughly between 10 and 100 microns, is a great handicap, and that these microfossils, with the exception perhaps of the spores, were interesting only from an academic point of view.

The micropaleontologists of today, however, can proudly state that they have come a long way during the last ten years in using just these kinds of small and smallest microfossils for stratigraphic, palecologic, and paleobiologic purposes. New laboratories have been added by many oil companies, and research work at universities has been greatly intensified since the last World War. New techniques and more powerful microscopes are now used and the designation "non-fossiliferous" in the vocabulary of the paleontologists is gradually disappearing since these protists are sought and used with profit in elucidating stratigraphic problems of drilling and exploring for oil and gas.

Time does not permit me to evaluate even in a short review the practical value of all groups or classes of microfossils. We all know the results attained with the help of the Foraminifera, Ostracoda, conodonts, et cetera, in the everyday work of the commercial paleontologists and stratigraphers all the world over during the last 38 years. There are more than 30 different groups of microfossils that can be used and will be used for stratigraphic subdivisions, age determinations, and reconstructions of environments and paleogeographic conditions of marine, brackish-water, and continental sediments. We will, therefore, single out a few groups of fossil protists, emphasizing those with an average size range between 5 and 200 microns, which will be increasingly of great value in our future stratigraphic work.

Raymond C. Moore has recently (1954) included all groups of protists, whether plant or animal, in their own kingdom. Zoologists and botanists may disagree with this proposition from an academic point of view, but the economic paleontologists will hardly take sides in this issue. For them, anything which is fossilized and can be used practically, whether plant or animal, small or large, is of importance in their daily work, and therefore has to be studied and evaluated for its usefulness.

The *diatoms*, colonial unicellular algae secreting a bivalved siliceous test, live in almost all waters, fresh, brackish, or marine, excepting those of highest salinity or temperature. They are tremendously prolific and one of the main food sources of all marine life; they are pelagic in their mode of life and, therefore, widespread from pole to pole and cover large tracts of the deep-sea

floor in the form of diatomaceous ooze. More than 600 genera and nearly 20,000 species, fossil and Recent, are now known. Geologically, there first true appearance dates back only to the Upper Cretaceous, where they abruptly appear in great numbers and variety of genera and species, indicating that they evolved from an older, more primitive unknown stock. Since their minute siliceous tests can readily be fossilized, their wide distribution, especially in Tertiary formations, should make them highly valuable for stratigraphic use, when their geologic occurrence is better known than at present. Their occurrence in continental deposits, in conjunction with pollen, offers much important palecologic information, and future intensive studies from the standpoint of applied micropaleontology will eventually establish them as good time-markers.

Many fresh-water deposits in Devonian, Lower Mississippian, Jurassic, Cretaceous, and Tertiary include minute spherical bodies, the oogonia (gyrogonites) of another algal group, the carbonate-secreting *charophytes*. They are important microfossils for this type of sediments and relatively easy to determine by their mode of coiling and the number of enveloping cells. Together with pollen, spores, and diatoms, aside from being good time-markers, they are excellent indicators for fossil fresh-water deposits.

Certainly the most spectacular advance in micropaleontology is due to the intensified study of fossil *spores* and *pollen*. The new science of palynology has lately become one of the most promising and important tools in the laboratories of oil companies. The use of spores in Carboniferous stratigraphy for correlating individual coal beds has long been known, and fossil pollen has been studied by botanists for the reconstruction of the climate during the Pleistocene, long before an attempt was made to use these tiny organisms in oil-field stratigraphy. Since all pollen and spores originate on land, and, in the case of pollen, are wind-swept and air-borne, they are deposited to the seaward in continental, brackish-water, and marine habitats. Their outer skin, the exine, is practically indestructible by any kind of acid, thus guaranteeing their fossilization in any facies or environment, and the enormous quantities released during flowering assures wide dissemination. This dissemination naturally decreases offshore, but a close study of the dispersal makes it possible to detect ancient shorelines. The stratigraphic value will be discussed at our meetings in a special symposium organized by the research committee of the Society of Economic Paleontologists and Mineralogists, in connection with other useful microfossils of about the same size range (5–100 microns) as, for instance, the *hystrichospherids* and the *peridinids* (*dinoflagellates*). The hystrichospherids, or "porcupine globules," are known to exist since the Upper Cambrian and have been recorded as fossils as late as the close of the Oligocene. Recently they have been recognized off the coast of Sweden and in the Mediterranean Sea, still living, but extremely rare. They are thought to represent cysts of marine unicellular phytoplankton, and, as fossils, are generally found in a ratio of several hundred specimens per hundred grams of sediments. Microscopic examination of small chips of siliceous and phosphatic nodules and flints (silex) has revealed a new world of fossil microplankton especially during the last 25 years. Their study, as well as that of the closely related peridinids or dinoflagellates, (flat, pentagonal or oval organisms known since Upper Jurassic time) indicates their increasing practical value in oil exploration.

Another group of very minute organisms, ranging in size from only 1 to about 100 microns, are the *coccolithophorids* and *discoasterids*, calcareous planktonic forms occurring in all depths of marine habitat and known since Liassic time. They are enormous producers of calcium carbonate and, therefore, most important as sediment-formers: Gümbel found 800,000 coccoliths in one cubic millimeter of Eocene sediment, and Tan Sin Hok calculated that there were more than 5 million in one cubic centimeter of a sample from the Sunda Islands. Biostratigraphically they indicate open-sea conditions. Some of the fossil species have recently been recognized as excellent time-markers, thanks to their tiny size and world-wide distribution; one species, for instance, has been recorded in the same stratigraphic position (Upper Eocene) in Trinidad, Barbados, Panama, New Zealand, and

France. Other species appear to have a similar narrow life-span and wide distribution. The study of these minute organisms, fossil and Recent, has been intensified with the help of the electron microscope.

The *silicoflagellates*, about 15–80 microns in size, are known since the Upper Cretaceous but are very rare in Recent seas, they constitute a class of microorganisms on the way to extinction. About a dozen genera are known fossil, but only one genus is still living. The siliceous skeleton is extremely well suited for fossilization. As more workers devote their time and patience to search for these organisms, especially when samples are prepared for pollen, spores, diatoms, and coccoliths, more knowledge will be gained regarding the occurrence and distribution in otherwise sparsely fossiliferous or non-fossiliferous sediments. There is no reason to doubt that silicoflagellates will become very useful stratigraphic markers in pre-Cretaceous as well as post-Cretaceous sediments.

As was the case with the Foraminifera and Ostracoda up to the advent of applied micropaleontology (1917), the *radiolarians*, exclusively marine pelagic animalcules with a siliceous test of esthetic beauty occurring in practically all seas and sediments, still bear the stigma of having little value for stratigraphical purposes because of the long geologic range of many of them. They are well known as to their morphology and taxonomy, and furnish excellent paleco-logic information about depth and habitat of their former environment. Known since the Cambrian and in size somewhat greater than the afore mentioned groups of micro-organisms, their wide occurrence and abundance (especially in siliceous sediments, novaculites and porcellanites) should stimulate a more intensive scrutiny by the micropaleontologists. They are potential future markers for stratigraphic and palecologic purposes not only for local but also for intercontinental correlations.

Finally, mention should be made of another group of highly useful microfossils, the flask-shaped pelagic and marine *calpionellids* with a size of about a tenth of a millimeter. They are excellent markers for the subdivision of lithographic and sublithographic limestones in the time-span from the Upper Jurassic to the Lower Cretaceous and apparently indicate warm tropical waters. *Nannoconus*, an organism of 5–50 microns in size, of uncertain taxonomic position, generally occurs between Neocomian and Albian beds, commonly as a rock-former, following in time the calpionellids and apparently preceding the appearance of *Globotruncana* in the geologic column. Together with the infusorian calpionellids, *Nannoconus* is extremely useful for a biostratigraphic subdivision of the masses of "non-fossiliferous" dense limestones of Upper Jurassic and Lower Cretaceous age.

It is a curious or rather regrettable fact that, aside from the pollen and spores, so far only a very few scientists are actively engaged in studying and evaluating most of the mentioned groups of micron-sized microfossils. We are, however, only at the beginning of their study, and the requirements of the oil companies call for more and more research and practical application in these neglected fields of micropaleontologic activity. The occurrence of oil in continental and semi-continental beds is a stimulus in this direction, and the next decade will certainly bring to light many micropaleontologic facts hitherto unsuspected or not yet available.

Regardless of the lithology, facies, or geologic age of a rock sample, it is now up to the modern micropaleontologist to select *any* kind of microfossils; study the occurrence, evolution, morphology, and taxonomy; and apply the proper methods, techniques, and optical instruments in order to use these documents of ancient microscopic life for stratigraphic and ecologic purposes. Such studies will ultimately pay high dividends, and the long hours behind the microscope will certainly be rewarded in many ways, and also satisfy the eager student from an artistic and esthetic point of view. It is the privilege of the micropaleontologist to deal with minute microscopic fossils, to disentangle their secrets, to make them available for practical purposes, and to use phantasy and philosophy in order to understand and classify the microbios which so abundantly populated ancient lakes, ponds, seas, and continents. The satisfaction of his time-consuming and patience-requiring studies lies in his contribution to

the advance and progress of science, and more specifically of the oil industry, which turns the wheels of our present and future economy and welfare.

Applied and academic micropaleontology progresses rapidly and healthily without interruption, thanks to the inbred curiosity and scientific pioneer-spirit of the student who previously was content to use the stereoscopic binocular microscope but now must have at his disposal a high-powered biologic microscope in order to penetrate deeper and deeper into Nature's secrets. The time will not be far off when he will have to turn to the electron microscope, not only for satisfying his curiosity, but in search of new approaches to solve his everyday geologic problems. The trend in micropaleontology is from small to smaller and smallest fossils. As Carey Croneis said: "Even the most abstruse academic subject has a miraculous way of turning out to have a concrete financial application." This has been true for the last forty years or so of applied micropaleontology and will be equally true in years to come. May I add that as long as the oil companies explore for oil anywhere on this wonderful globe of ours, there always will be a micropaleontologist until the very last oil well has been drilled. And this last micropaleontologist will possibly use micropaleontological methods and base his age determinations and his deductions on the paleobiology, palecology, and paleogeography of microfossils, which are either unknown to us at present, or have not yet attained the practical value which they deserve.

We, economic paleontologists and mineralogists, and more especially we, the future "*microtero*-paleontologists," look hopefully and with great faith, confidence, and anticipation into the future of our science.

## RESEARCH COMMITTEE SYMPOSIA

Tuesday, March 29, 2:00 P.M.

Keystone Room, Hotel Statler

## SYMPOSIUM: SEDIMENTARY ASPECTS OF RESTRICTED BASIN DEPOSITION

*Presiding:* E. C. DAPPLES, Northwestern University, Evanston, Illinois AND BERNHARD KUMMEL, Harvard University, Cambridge, Massachusetts

### PART I—PRESENTATION OF PAPERS

### 1. SYSTEMS OF SEDIMENTATION AND THEIR PHASES

PAUL D. KRYNINE

Pennsylvania State University, State College, Pennsylvania

The comparative description—and classification—of any item in order to be useful, must operate with certain common denominators, or "polar end members." These are frequently not obvious. Ideally a valid descriptive pole has a definite, almost unique genesis.

In sedimentary basins of deposition, the time honored classification of "environments," from marine sandbars to continental flood plains has hardly ever yielded usable criteria for actual differentiation of a sample. Its categories are paramorphological and not polar. The same, by the way, is true of the current classification of geosynclines, which may be considered as "environments" on a much larger scale.

Systems of sedimentation are made up of depositional loci (so-called "environments") which are "frozen samples" of dynamic genetic conditions which are basically as follows:

1. Ease or difficulty of exit of the load. Basic divisions are (a) "Thoroughfares," such as channels of every type, sandbars, dunes, etc.; (b) "Dead ends," namely interfluves of every breed and hue, melting glaciers, flocculation areas; some "barred basins," mud flows (the very fashionable turbidity currents are not included, since the amount of objective significant quantitative petrographic data presented in support of their volumetric importance so far is nil). A further subdivision of "thoroughfares" divides them into those with a linear exit (channels) against those with a lateral exit (dunes).
2. Regimen of current, broken down into: (a) Velocity (theoretically expressed by moment measures for traction and suspension). (b) Time distribution pattern for effective velocity, particularly the "null velocity" of settling. This means in effect ratio of life

time of depositional locus occupied by effective velocities. The balance is immaterial.

On the basis of the preceding, a tenable and usable description and classification of sedimentary loci or phases becomes possible, essentially because these polar genetic concepts correspond to objective, observable and measurable petrographic criteria, which are also polar. It must be understood that the normal sedimentary system consists of several phases, which frequently cannot exist independently and separately (channel and floodplain). Within this scheme, which is briefly described, a "barred basin" is a chemical dead-end system with several detrital, chemiclastic and fixed crystalline phases, some of them relatively open exit.

All of these phases co-exist (?) in time, and due to tectonic control may follow each other in space, even cyclically (particularly true on a rigid substratum).

The geologic concept of "facies" may refer to passage from one system into another, or to the predominance of a phase within a system. Since this difference is large, it follows that the classical confusion on the subject is also not small.

## 2. STARVED BASINS

HUGH N. FRENZEL
Midland, Texas

A starved basin is defined as a basin which received a thinner section of deposits than adjoining areas, because the rate of subsidence was materially greater than the rate of deposition. In contrast to ocean basins which have remained starved over long periods of time, intracratonic basins, that show these characteristics, were starved for only portions of their history.

Typical and well known examples are the upper Pennsylvanian Midland basin and the upper Guadalupe Delaware basin. These basins illustrate the range and variation in basins which are called starved. A starved basin condition existed in the Midland basin during upper Pennsylvanian time as shown by the thin black shale section which grades into a thick section of limestone around the margin. The upper part of the Guadalupe series in the Delaware basin is interpreted as a starved basin deposit because these rocks are thinner than the correlative reef and shelf sediments and were deposited 2000 feet below them.

A basin becomes starved when the supply of clastics is restricted by such factors as distance from source, intervening basins or troughs, and the inability, because of increasing depth, of normal waves and currents to carry their traction load beyond the basin margin. Also, the depth of the water prevents or inhibits the development of carbonate deposits.

## 3. CHEMICAL EQUILIBRIA UNDER RESTRICTED MARINE CONDITIONS

ROBERT M. GARRELS
U. S. Geological Survey, Washington 25, D. C.

Restriction of circulation of marine waters commonly sets up a chain of events with drastic consequences to the sediments deposited. Oxygen is exhausted, organic material is preserved, an entirely new biology is developed, and the solubilities of many inorganic compounds are drastically altered from that of a normal marine environment. In the last decade, much work has been done both on natural restricted environments and on theoretical and experimental systems that have direct application to the natural restricted environments. A summary is given here of several theoretical and laboratory investigations that have significance in environments of restricted circulation. Eh-pH diagrams are provided for iron, sulfur, selenium, lead, zinc, copper, vanadium, uranium, and manganese.

## 4. SEDIMENTARY ENVIRONMENT OF IRON FORMATIONS

ARTHUR L. HOWLAND* AND HAROLD L. JAMES
Northwestern University, Evanston, Illinois, and U. S. Geological Survey, Menlo Park, California

Sedimentary iron formations, containing from 15 to 40 per cent iron, are common in the Precambrian, but occur in a number of other geologic periods and are found on all continents. They are predominantly chemical sediments, intermixed with minor amounts of clastic material and interstratified with shale, sandstone, and limestone. Diagenesis and later replacement seem to have had only a minor role in their formation. A marine origin of most is probable in view of their occurrence in sequences of normal marine characteristics in both Precambrian and younger periods. The iron-bearing minerals—sulfides, carbonates, oxides, and silicates—indicate a wide range in degree of oxidation of the iron at the time of precipitation or during diagenesis. Silica, in the form of chert, is characteristic of some members, particularly in the iron formations of Precambrian age.

Recent studies have emphasized the applicability of modern concepts of stratigraphic analysis to the study of iron formations, even where structural complications are considerable. The concentration of iron and silica indicates conditions of deep weathering for long periods. The dominance of chemical sedimentation may be attributed to low relief of adjoining lands in combination, at least in some cases, with the existence of barred basins that permitted the persistence of special chemical environments and the exclusion of clastic material.

* Person presenting paper.

## PART II—PANEL DISCUSSION

Discussion of each paper will be deferred until all papers have been presented. Topics covered by the papers will be discussed in a special panel session which will be held following the papers. Approximately 40 minutes will be available for the discussion. Panel members will consist of all speakers and co-authors.

## Wednesday, March 30, 9:00 A.M.

## Keystone Room, Hotel Statler

## SYMPOSIUM: SPORES, POLLEN AND OTHER MICROFOSSILS USEFUL IN OIL EXPLORATION

*Presiding:* W. S. HOFFMEISTER, Carter Oil Company, Tulsa, Oklahoma, AND ELSO BARGHOORN, Harvard University, Cambridge, Massachusetts

### SPORES AND POLLEN—A NEW STRATIGRAPHIC TOOL FOR THE OIL INDUSTRY

RAYMOND D. WOODS
Humble Oil & Refining Company, Houston, Texas

Interest in the use of spores and pollen as a stratigraphic tool has recently been accelerating in the oil industry. It has been demonstrated in a number of areas that the distribution of these fossils is adequate for stratigraphic work and several major companies now have full-time paleobotanists on their research staffs. The science of pollen analysis began with the studies of the Swedish geologist Lennart von Post in 1916. Since then these plant fossils have been used in several parts of the world but primarily for the correlation of coal beds and for interpretations of Quaternary geology. The new emphasis on a wider application of these fossils to general stratigraphic problems is indicated by the special section of *The Micropaleontologist* recently assigned to palynology and by the proposal of a new botanical journal, under editorship of Erdtman, which will contain a section on the use of spores and pollen as guide fossils for pre-Quaternary geology. Certain of these windblown fossils offer a distinct advantage in permitting correlation of strata deposited under ecologic conditions unfavorable for the distribution of marine or fresh water animals. Certain other forms have been suggested as indicators of depositional environments. In addition, current research on spores and pollen has revealed the distribution of heretofore little known microfossils, particularly the "hystrichs" which are proving to be as useful as plant remains in stratigraphic work.

### 2. MISSISSIPPIAN PLANT SPORES FROM THE HARDINSBURG FORMATION OF ILLINOIS AND KENTUCKY

WILLIAM S. HOFFMEISTER,* FRANK L. STAPLAN AND RAYMOND E. MALLOY
Carter Oil Company, Tulsa, Oklahoma

Plant spores from core samples of three wells and five outcrop samples of the Hardinsburg formation of upper Mississippian age from Kentucky and Illinois are described. The spore assemblage consists of 19 genera including 3 proposed as new and 59 species of which 37 are new. The paper includes methods of sample preparation, discussion of literature on Mississippian plant spores, spore assemblages of the Hardinsburg formation, taxonomy, and systematic description of genera and species.

The difference in the technique employed in the maceration of carbonaceous shale from that in the maceration of coal is discussed. Literature on Mississippian spores is meager and vague as the few articles concerning spores of this age refer to coal seams which have not been definitely correlated with type Mississippian sections.

### 3. STRATIGRAPHIC DISTRIBUTION OF PENNSYLVANIAN SPORES†

ROBERT M. KOSANKE
Illinois State Geological Survey, Urbana, Illinois

Many preliminary examinations have been made of the spore and pollen assemblages of Pennsylvanian deposits within the past 10 to 20 years. Some have been entirely concerned with academic descriptions whereas others have been more largely devoted to applied practices related to stratigraphy. It is this latter phase of research with which we are concerned in this paper. Academic paleoecological investigations cannot be separated from stratigraphy.

Straight-laced stratigraphic correlations based entirely on "index fossils" may find many embarrassing pitfalls in the years ahead if the causal factors of plant distribution in time and space are not given proper recognition and study. Interpretation of stratigraphic distribution cannot be made without serious efforts to understand primary plant communities, succession, and dominant communities within a given deposit or those developed throughout Pennsylvanian time.

Published and unpublished data are used in delineating the stratigraphic distribution of genera and species of spores of Pennsylvanian deposits. Suggestions are made for harmonizing

* Person presenting paper.

† Published with permission of the Chief, Illinois State Geological Survey.

disjunct stratigraphic ranges, and for the evaluation of interbasinal correlations.

## 4. STRATIGRAPHIC CORRELATIONS IN PALEOZOIC STRATA

### The Occurrence of Important Plant Spore Species in European, North American, Chinese, Australian and Brazilain Coal Basins

Gerhard Kremp
Pennsylvanian State University, State College, Pennsylvania

The spores of North American Pennsylvanian areas have been well described and illustrated, especially by Kosanke, 1950, Cross, 1947, and other authors. Some details of stratigraphic distribution are also given in these publications.

Comparison with the European data shows surprising conformity. Thus 37 species out of 47 figured by Kosanke, 1950, from the upper part of the Tradewater, Illinois, are the same or nearly the same as in the Ruhr Carboniferous. In the Upper Westfal B.R. Potonie and Kremp, (1955, paper in press) studied 535 spore species from Paleozoic strata and placed them in genera. Of this total they described and figured 185 species from the Ruhr Carboniferous and found that 119 of these species had already been described in Middle European papers by 1945. Twenty-seven other species had been named in North America, four in east and northwest Europe and four in the Kaiping basin (China). These had not previously been recognized in the Ruhr Carboniferous. A large proportion of the species of German origin were already known in North America. In some cases the America authors chose the original names of Ibrahim and Loose, in others they preferred new names. It is believed that the new names would not have been given if in the old papers there had been good photographs instead of drawings which were difficult to compare.

In the last twenty years we have been able to get an approximate picture of the distribution of spores in European Paleozoic strata. The picture gained of the stratigraphic distribution of spores in European Paleozoic strata is nearly the same as that known in the United States.

Especially marked is the similarity of the occurrence of *Densosporites*. It seems to be the same with the spore genus *Lycospora*. Today workers are able not only to correlate coal seams within the same coal basin, but also between different basins. It is to be hoped that eventually our enhanced knowledge can also successfully settle the problems of stratigraphic correlation between North American and European coal basins.

From the dissertation of Imgrund, 1952, it has been shown that the spore distribution in the Kaiping basin (China) is in conformity with those in Europe and Illinois.

The spore flora of Gondwana countries seems to include many genera unknown in the Northern Hemisphere. In the Gondwana flora, three different groups of spores are to be distinguished:

a) Spore genera unknown in the Northern Hemisphere.
b) Spore genera of simple construction, which may be recognized from all ages and all continents.
c) Spore genera also known in the Paleozoic strata of the Northern Hemisphere which, there, are of significant stratigraphic value.

All these spore genera, in the Northern Hemisphere, are first represented in the late Paleozoic, mostly at the beginning of the Permian. The predominant genera of the Carboniferous of the Northern Hemisphere appear to be absent in Gondwana coals. It is particularly striking that the *Densosporites* group which extends from the "Lower Carboniferous" to the end of the "Upper Carboniferous" is not found in Gondwana coals. The same seems to be the case with *Lycospora*, *Florinites* and other important genera. For these reasons it may be possible that at least the "Upper Coal Measures" of Australia are of upper Permian age. The *Glossopteris* flora of the southern continents may have existed in middle Pennsylvanian times in cooler areas. This flora might also be found in northern regions if investigations could be made of coal or clay samples from such cooler areas. More could be said about these aspects if better evidence were available from the southern continents.

## 5. TERTIARY SPORES AND POLLEN RELATED TO PALEOECOLOGY AND STRATIGRAPHY OF CALIFORNIA*

W. L. Norem
California Research Corporation, La Habra, California

When the use of fossil plant spores and pollen was applied to geologic-age dating and stratigraphic correlation, a powerful new tool was introduced in geology. It made possible the correlation and dating of many sedimentary strata that lack other biologic time markers. However, the stratigraphic relationships of any fossil group may not be correctly interpreted unless the ecological relationships of the parent organisms are known. The extensive studies of macroscopic paleobotany in western North America provide a background of botanical and climatic history for the evaluation of the stratigraphic relationships of fossil spores and pollen.

R. W. Chaney, D. I. Axelrod and others have traced the floral changes and migrations during Tertiary time. The luxuriant floras that developed during the Cretaceous persisted in the Arctic regions until the Eocene and then migrated southward in response to cooling climates. Many genera representative of these Arcto-Tertiary floras reached California during the latter part of the Miocene and persisted there until the Pliocene when rising mountain ranges altered the rainfall pattern.

In California, the Tertiary sediments yield a

* Paper to be presented by W. J. Plumley, California Research Corporation, La Habra, California.

sequence of fossil pollen and spores extending from tropical and subtropical types in the Eocene, through the Arcto-Tertiary types of the upper Miocene and lower Pliocene into the predominantly coniferous forest types of the upper Pliocene and Pleistocene. In areas of continuous deposition, the changes in the microfloras are related to changes in climate. Abrupt changes occur in the lower and upper Miocene and in the Pliocene. These abrupt changes of microfloras do not necessarily coincide with changes in the aquatic fauna indicating that climatic changes are not always reflected by changes in the aquatic environments.

## 6. MORPHOLOGY AND GEOLOGY OF THE HYSTRICHOSPHAERIDA

L. R. WILSON*, AND W. S. HOFFMEISTER
University of Massachusetts, Amherst, Massachusetts, and Carter Oil Company, Tulsa, Oklahoma

The Hystrichosphaerida constitute a group of organisms whose affinities appear to be with the Protista. They are single-celled structures with a chitinaceous wall which is frequently ornamented with spines, reticulation or extra net-like coverings. Sixteen or possibly seventeen genera are recognized. The geological range of the group extends from the Upper Precambrian to the Recent. Various genera are restricted to certain periods and species are restricted to shorter ranges. Approximately 1000 sandstone, shale and limestone samples have been investigated for hystrichosphaerids, and of these nearly 50 per cent contained fossils. Eighty-five per cent of the fossil-bearing rocks were shales and 15 per cent shaly limestones. Paleozoic hystrichosphaerids are associated with conodonts, scolecodonts, chitinozoa, brachiopods, corals, and crinoid parts. In Mesozoic and Cenozoic rocks hystrichosphaerids are found associated with Foraminifera, ostracodes spores and pollen. The ecological inferences from rock types and associated organisms is that the older hystrichosphaerids, like the Recent, were restricted to brackish and marine water. Modern species have been found in shallow to deep water which is brackish or marine, and from subtropical to arctic latitudes.

The Hystrichosphaerida because of their small size, diagnostic characters, great abundance and wide geographic distribution meet the requirements for applied micropaleontology.

* Person presenting paper.

## 7. MICROPALEONTOLOGY OF HOLOTHURIAN SCLERITES

DON L. FRIZZELL* AND HARRIET EXLINE (Mrs. Don L. Frizzell)
Missouri School of Mines and Metallurgy, Rolla, Missouri, and Rolla, Missouri

Fossil holothurians (Echinoderma, Holothuroidea) are known almost exclusively from isolated sclerites, microscopic calcareous particles that support the body of the animal. A unified classification is proposed, following principles of zoological nomenclature, to facilitate the use of these microfossils in micropaleontology. Nine families are defined, with 22 genera and 110 species.

Holothurian sclerites occur questionably in Ordovician rocks, ranging definitely from Devonian to Pleistocene. Except for relatively well known Carboniferous and Jurassic assemblages, knowledge of these microfossils is meager. Vertical and lateral ranges have not been established, although some Paleozoic species are known to be long-ranging, and the Mesozoic and Cenozoic species seem to have been shorter lived.

Holothurians are almost exclusively benthonic, crawling on the sea floor, clinging to rocks and seaweed, or burrowing in the substratum. They live in all seas and depths, but almost never in brackish water. Paleoecologically, sclerites indicate warm to cold marine water of normal salinity from littoral zone to moderate depths; those at greater depth having undergone contemporaneous solution. Reported occurrences are most common from clays, marls, shales, and sandy shales, and rare from limestones and the coarser clastics.

* Person presenting paper.

Wednesday, March 30, 1:30 P.M.
Main Ballroom, Hotel Statler

JOINT TECHNICAL SESSION

PAPERS OF GENERAL INTEREST

Thursday, March 31, 9:00 A.M.
Keystone Room, Hotel Statler

## GENERAL PALEONTOLOGY AND STRATIGRAPHY

*Presiding:* M. L. THOMPSON, University of Kansas, Lawrence, Kansas AND WALTER YOUNGQUIST, University of Kansas, Lawrence, Kansas

### 1. STRATIGRAPHY OF LATE CRETACEOUS AND EARLY TERTIARY FORMATIONS IN NEW JERSEY

STEVEN K. FOX, JR., AND RICHARD K. OLSSON*

Rutgers University, New Brunswick, New Jersey, and Princeton University, Princeton, New Jersey

Stratigraphic analysis of late Cretaceous and early Tertiary formations in the Coastal Plain of New Jersey reveals the following:

1. The Upper Cretaceous Navesink, Red Bank, and Tinton are formations with distinct microfaunas indicating time differences.
2. A distinctive new late Cretaceous microfauna from the Red Bank formation contains 84 species. Although many forms are new, a sufficient number indicate correlation with the latest Navarro of the Gulf Coast section. The fauna is easily differentiated from that of the underlying Navesink formation.
3. A completely new microfauna of five species from the Tinton formation differs considerably from that of the Red Bank. Because of the latest Navarro age assigned to the Red Bank, the Tinton may well be post-Navarro and pre-Midway.
4. A new facies microfauna from the lower part of the Hornerstown formation is dwarfed and contains two arenaceous species. Apparently bottom conditions were not favorable for prolific foraminiferal development.
5. A well developed microfauna of 150 species in the uppermost Hornerstown is associated with abundant *Oleneothyris*, *Gryphaea*, and *Polorthus*. Appearance of this fauna suggests more favorable bottom conditions than in the lower Hornerstown. The presence in the fauna of 31 species restricted to the Midway of the Gulf Coast implies strong Paleocene affinities. The occurrence of 57 new species in the Hornerstown reveals the newness of the assemblage and an environmental niche peculiar to New Jersey.
6. A microfauna of 70 species from the basal part of the Vincentown formation contains a mixture of typical Paleocene forms in association with new Eocene elements characteristic of the upper part of the Vincentown. It is assumed that the Paleocene forms have been largely reworked into the lower five feet of the Vincentown where they occur with fragments of *Oleneothyris*, *Gryphaea*, and *Polorthus* and with considerable reworked typical Hornerstown greensand.
7. Comparison of the type Vincentown microfauna with the Hornerstown and basal Vincentown assemblages described above reveals that the type Vincentown is clearly Eocene in age. It contains no diagnostic Paleocene forms.
8. Stratigraphic evidence indicates an unconformity between the Cretaceous and Tertiary formations. The Hornerstown rests successively from northeast to southwest on the Tinton, the Red Bank, and the Navesink. In each case the Hornerstown lies upon a weathered surface and the basal few feet contain fragments of the underlying formation.

* Person presenting paper.

### 2. EDWARDS LIMESTONE FOSSILS AS DEPTH INDICATORS*

KEITH YOUNG

University of Texas, Austin, Texas

The Edwards limestone section of Hill, Bosque, and Johnson counties, Texas, contains four distinctive zones of fossils. In ascending order these are: (1) Hexacoralla, Stylinidae; (2) Pelecypoda, Diceratidea and Monpleuridae; (3) Pelecypoda, Caprinidae, and (4) Pelecypoda, Radiolitidae and *Chondrodonta*. The shell structure of the pelecypods increases in sturdiness and thickness in ascending order and parallel to the zones of fossils. These zones of fossils and the concurrent

* Publication authorized by the Director, Bureau of Economic Geology, The University of Texas.

patterns of shell structures are interpreted as a depth indicator for the environment of the Edwards limestone sea. The upper surfaces of the radiolitid and *Chondrodonta* zone are thought to be comparable to the upper surfaces of some modern reef complexes.

### 3. LATE CRETACEOUS CEPHALOPODS FROM SAUDI ARABIA*

W. M. FURNISH† AND A. K. MILLER
State University of Iowa, Iowa City, Iowa

Upper Cretaceous limestones, called the Aruma formation by Steineke and Bramkamp, crop out in an arcuate belt through the interior of the Arabian peninsula. These strata are separated from older Cretaceous sandstones by a prominent unconformity but show little evidence of a missing interval below the overlying Paleocene dolomite. Almost continuous exposures for over 400 miles (between 22 and 28 degrees north latitude) contain a variety of larger foraminifers, corals, echinoids, rudistids and other mollusks including both ammonoids and nautiloids. The ammonite *Sphenodiscus* indicates that the greater portion of these beds are uppermost Cretaceous (Maestrichtian) in age. Some of the associated forms, *Cimomia* and *Deltoidonautilus*, have previously been regarded as characteristic of the early Tertiary

### 4. THE CARBONIFEROUS GUIDE FOSSIL, *TYLONAUTILUS*, IN AMERICA

A. K. MILLER† AND W. M. FURNISH
State University of Iowa, Iowa City, Iowa

In the British Isles, Belgium, and Germany, *Tylonautilus* has long been regarded as an index to the *Eumorphoceras* zone of the lower Namurian, at the base of the Upper Carboniferous. A typical individual was recently sent us from the Fayetteville formation in northeastern Oklahoma. It enabled us to recognize that a small specimen described long ago from the Caney shale of southern Oklahoma is an immature representative of the same genus. Both the Caney and the Fayetteville carry goniatites, including *Eumorphoceras*, like those of the European Namurian.

### 5. CRITERIA FOR THE RECOGNITION OF SPECIES AND SUBSPECIES IN UPPER TRIASSIC METOPOSAURID AMPHIBIANS

EDWIN H. COLBERT AND JOHN IMBRIE‡
The American Museum of Natural History, New York, New York, and Columbia University, New York, New York

The systematics of North American Upper Triassic metoposaurid amphibians is reviewed in the light of three unusually large population samples from Arizona, New Mexico, and Texas, and a fourth from Wyoming. Qualitative examination indicates that seven readily determinable morphologic characters show significant variation: antorbital length, postorbital length, length of skull roof, orbital width, greatest skull width, clavicle width, and clavicle length. Bivariate statistical analysis of logically related pairs of these variates supports qualitative judgment that four morphologically distinct groups can be recognized. Three lines of evidence are employed in an attempt to arrive at the most meaningful taxonomic treatment of these groups: (1) The known biogeography of the essentially contemporaneous Triassic populations. (2) Quantitative estimates of the amount of morphological overlap among the four groups. (3) The amount of morphological overlap in comparable skeletal characteristics among randomly selected populations of modern mammalian species and subspecies. It is concluded that two subspecies of one species are represented.

Taxonomic concepts and biometrical techniques employed in this study may be readily applied to analogous taxonomic problems involving invertebrate fossils.

### 6. SUBSURFACE GEOLOGY OF COKE COUNTY, TEXAS

SAMUEL P. ELLISON, JR.
University of Texas, Austin, Texas

An array of facies changes, reef masses, and porosity pinchouts dominate the gentle westward dipping Pennsylvanian and Permian strata. Faulting and folding create complex petroleum reservoir-finding hazards in Cambrian and Lower Ordovician beds below the basal Pennsylvanian angular unconformity along the Bronte uplift in the eastern part of the county. Buried cuestas and isolated hills of the pre-Pennsylvanian topography also account for some reservoirs. Wildcat well density has now reached the point where modern electrical logs become efficient tools for solving lithologic problems and stratigraphic correlations. The trend patterns of facies, reefs, porosity pinchouts, buried topography, faults and folds are applicable to the search for petroleum in adjacent counties on the Eastern Shelf and Concho Arch.

### 7. ENDOTHYROID ZONATION IN THE MISSISSIPPIAN OF THE ROCKY MOUNTAINS

EDWARD J. ZELLER
University of Wisconsin, Madison, Wisconsin

Through the use of endothyroid Foraminifera it has been possible to recognize four widespread faunal zones in the Mississippian rocks of western United States. The faunal succession of the endothyroids and the lateral extent of the four faunal zones were determined by thin-section studies of samples from twelve measured sections distributed along the Cordilleran trough from Arizona to Montana.

* Presented with the permission of Arabian American Oil Company.
† Person presenting paper.
‡ Person presenting paper

The lowermost zone is based upon the presence of a new genus of endothyroid foraminifers and is considered to be Kinderhookian in age. Rocks containing this fauna are overlain in most areas by those with an especially distinctive new species of *Plectogyra*, most probably Osagean in age. Both of these zones are typically developed in the Madison limestone of Utah, western Wyoming, and Montana.

The two upper endothyroid faunal zones are each characterized by a new species of the genus *Endothyra*. The lower of these zones is Meramecian in age and all of the forms present show close similarity to those in the Salem limestone of the Mississippi Valley area. The species which distinguishes the upper faunal zone is similar to a form in the Ste. Genevieve, but the associated endothyroids seem to have more affinities to the fauna from the type Chesteran. Rocks containing one or both of the upper faunal zones have been found in the Paradise, Escabrosa, and Redwall formations in Arizona and in the Brazer and several thin and unnamed limestones in Utah.

## 8. CLOSE ZONATION OF UPPER CRETACEOUS GLOBIGERINAL SEDIMENTS BY ABUNDANCE RATIOS OF *GLOBOTRUNCANA* SPECIES GROUPS

H. V. Dunnington

Iraq Petroleum Company, Kirkuk, Iraq

Indurated Upper Cretaceous globigerinal limestones have been studied in randomly oriented thin sections providing intersections of large populations of *Globotruncana* species.

The ratio between the numbers of intersected *Globotruncana* individuals showing one peripheral keel and of those showing two or more such keels is almost constant for any stratigraphic horizon, regardless of facies, within northern Iraq.

The ratios vary progressively with age in any vertical sequence, thus providing a rather precise key to stratigraphic position within the age limits of the formations considered.

Detailed observations have been restricted to Maestrichtian-upper Campanian sediments of northern Iraq. It is possible that the values of the ratios may be of world-wide stratigraphic significance, and also that the progressive change may be continuous through sediments of Cenomanian to Maestrichtian age.

## 9. ENDOTHYROID FORAMINIFERAL FAUNAS FROM THE LOWER CARBONIFEROUS OF ENGLAND AND ALGERIA

Doris E. Nodine Zeller

University of Wisconsin, Madison, Wisconsin

An abundant and highly diversified fauna of endothyroid Foraminifera was found in Lower Carboniferous limestones collected in England and Algeria. Comparison of the Lower Carboniferous faunal succession with that of Mississippian rocks in the United States reveals several striking similarities as well as some marked differences.

Certain specimens of *Plectogyra* from the Z zone in England are very similar to a new species in the upper Madison (Osagean?) of Utah, Wyoming, and Montana. The S zone contains a group of planispiral forms which have no known counterpart in American faunas. D zone assemblages from England contain both plectogyroid and planispiral forms which are similar to American Chesteran faunas as well as planispiral species which are totally different. *Parastaffella*, which is not present in Mississippian rocks of America, occurs high in the D zone. The European endothyroid faunas show greater similarity to the Mississippian faunas of the Cordilleran geosyncline than they do to the faunas of the mid-continent region.

Specimens from the upper Viséan at Taghit, Algeria, seem to be conspecific with *Plectogyra phrissa* from the Kinkaid limestone (upper Chesteran) of Illinois. The primitive fusulinid genus *Parastaffella* also occurs in upper Viséan rocks in Algeria.

Associated with the endothyroid faunas are two interesting genera of Foraminifera. *Howchinia bradyana* (Howchin), previously known only from England, has been found in samples from the upper Viséan at Taghit, Algeria. *Archeadiscus karreri* Brady, known to occur in the upper Viséan of Europe, has also been discovered in beds of the same age at Igli, Algeria.

## 10. FORAMINIFERA FROM THE BEAUFORT AND CHUKCHI SEAS

Alfred J. Carsola

U. S. Naval Electronics Laboratory, San Diego, California

Foraminifera populations in 62 sediment samples from the eastern Chukchi and the Beaufort Sea are generally small.

Planktonic Foraminifera are generally rare, but in a few samples they are the dominant forms found in the bottom sediments. The principal planktonic species is *Globigerina pachyderma* Ehrenberg.

The benthonic assemblage in the Chukchi Sea differs somewhat from that in the Beaufort Sea, probably as a consequence of the temperature barrier in the surface waters which separates these two seas. A depth zonation of benthonic faunas exists, with three zones being delineated. One is shallower than 65 m., one lies between 65 and 450 m., and a third zone is found in water deeper than 450 m. Indications are that these zones are largely dependant on sea surface temperature, which affects ice cover and thus organic production, and ultimately affects the ecologic conditions obtaining near and on the sea floor.

## 11. ANCESTORS OF THE QUAHOG

H. B. Stenzel

University of Houston, Houston, Texas

The common living hard-shell clam of the North American east coast, *Mercenaria mercenaria* (Linné, 1758), commonly known by its

Algonquian Indian name quahog, is the type species of *Mercenaria* Schumacher, 1817. The only other living congener is *M. campechiensis* (Gmelin, 1791) from the south coast. The genus is abundantly represented by several species and many individuals in the Oligocene, Miocene, and Pliocene deposits of the Gulf and Atlantic Coastal Plains. Because it is not found outside this region, it is evidently a provincial stock unable to spread. Hence its ancestors must be found in the Coastal Plains.

*Mercenaria* is the only Oligocene to Recent genus of the Veneridae that has rugose nymphs; it is also one of the few having a thick shell with crenulate margins and a peculiar radiating shell-wall structure created by the growing crenulations. Below the Oligocene, the only genus having such features is *Rhabdopitaria* K. Van W. Palmer, 1927, with the type species *R. astartoides* (Gardner, 1923) from the middle Eocene of Texas. This middle to upper Eocene genus is provincial in the Gulf Coastal Plain and ancestral to *Mercenaria*. Rapid evolution at the Eocene/Oligocene turn is responsible for the loss of the left anterior lateral hinge tooth and its corresponding socket in the right valve, present in *Rhabdopitaria* and lacking in *Mercenaria*, and the subsequent shifts of some of the hinge teeth.

Present classification of the family, based on the dentition, separates the two genera into different subfamilies, unjustifiably so. Dentition is a progressive feature in this family and not so reliable for classification as are the conservative nymphal rugae and crenulate shell margins.

### 12. SALT DOME STRATIGRAPHY—LOWER GULF COAST

SHEPARD W. LOWMAN
Rensselaer Polytechnic Institute, Troy, New York

The stratigraphy of salt domes is divisible into (a) regional stratigraphic setting of the domes and (b) characteristic effects produced by domes on local stratigraphy. Under the regional category an attempt is made to distinguish those features which are essential to salt dome formation. In the local class the effects produced by shallow and deep-seated domes are considered. Discussion is limited to the lower Gulf Coast of Texas and Louisiana.

## PAPERS TO BE READ BY TITLE

### FORAMINIFERA OF THE AUSTIN GROUP IN NORTHEAST TEXAS*

CHARLES L. MCNULTY, JR.
Continental Oil Company, Roswell, New Mexico

This research involves the arcuate belt of Austin outcrop extending through Dallas, Collin, Grayson, and Fannin counties of northeast Texas. The area is located on the northwest flank of the East Texas basin, where the strata dip gently south and east. Here the Austin group includes a calcareous facies, extending from Dallas County northward to Grayson County, and an argillaceous facies, extending from Fannin County eastward. Correlation of these facies has been a subject of controversy.

Although 143 foraminiferal species have been reported from the Austin, the low density and vague stratigraphic location of sample localities justify a systematic examination of its microfauna. Such examination was the primary objective of this study. In addition, the research anticipated some basis for zonation of the Austin group and clarification of the relations of calcareous and argillaceous facies.

Approximately 300 samples were collected and their stratigraphic position determined accurately by surveying.

The foraminiferal content of the samples includes 148 species, 11 of which are new, 8 possibly new, and 38 hitherto unreported from the Austin of Texas.

Nineteen species overwhelmingly dominate the faunal population and, in varying proportions constitute from 75 to 90 per cent of a given faunule population. Vertical variation in relative abundance of the 19 species reveals a gradual change from pelagic to benthonic types during the time of Austin deposition.

Fourteen species may be considered diagnostic of Austin strata, *Citharina texana* (Cushman) being the most useful by reason of its persistence.

The obvious dissimilarity of Austin-Eagle Ford faunas and the striking similarity of Austin-Taylor faunas, suggest that the Upper Cretaceous of Texas may be subdivided into two series at the Eagle Ford-Austin contact.

The fauna of the Austin group is divisible into a lower and upper fauna at the zone of *Exogyra ponderosa* Roemer (?), which appears to mark a hiatus. The lower fauna is named the normal Austin fauna and is characteristic of all the calcareous facies except its uppermost strata. The upper fauna is named the Gober fauna and is characteristic of all the argillaceous facies except its lowermost strata. Each fauna defines a faunal zone that can be traced along strike.

Along strike the unconformity of the *Exogyra ponderosa* Roemer (?) zone gradually truncates strata of the normal Austin faunal zone, causing it to thin northward. Conversely the Gober faunal zone, which is thickest in northern Fannin County, thins southward.

Uppermost strata of the Gober faunal zone change facies southward from chalk to marl and have been included hitherto in the Taylor group in Collin and Dallas counties. It is recommended

* Abstract of dissertation submitted to the Graduate School, University of Oklahoma, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1955.

that these lowermost "Taylor" strata, which have been demonstrated to be a mappable unit, be removed from the Taylor group and assigned to the Austin group.

### THE MEGAFAUNA OF THE FLORENA SHALE OF SOUTHERN KANSAS

BRUCE H. WALKER
Richmond Petroleum Company, Bogotá, Colombia

The megafauna of the Permian Wolfcampian Florena shale of southern Kansas is described. Twenty-two genera and 30 species are recognized. The 22 genera in the collection are represented by one coral, eight brachiopods, one ammonoid, seven pelecypods, four gastropods, and one trilobite. All of the genera, with the exception of the ammonoid, are present in the Pennsylvanian system. This is the lowest reported occurrence of *Paraceltites*.

The most noteworthy feature of the fauna is its dominant Pennsylvanian aspect. Twenty-one of the genera and 20 of the species are found in the Florena and in Pennsylvanian rocks below. The faunal similarity indicates a very close relationship in time between the two systems and testifies to their similarity of ecologic conditions and to a lack of any great time break between the Pennsylvanian and Permian systems in this region. The Florena fauna compares quite closely to those of other Wolfcampian horizons of approximately the same age in Texas, New Mexico, Arizona and Utah. The presence in the Leonardian series of 15 of the 22 genera found in the Florena shale testifies to the long range of those genera.

## Thursday, March 31, 1:30 P.M.
## Main Ballroom, Hotel Statler
## JOINT TECHNICAL SESSION
## PAPERS OF GENERAL INTEREST

### ANNUAL BUSINESS MEETING

The annual business session of the Society was called to order at 4:30 P.M., Tuesday, March 29, by Hans E. Thalmann, president, who introduced the officers for the new year as follows: President, Francis J. Pettijohn; Vice-President, Robert R. Shrock, Secretary-Treasurer, Samuel P. Ellison, Jr.

It was moved by Samuel P. Ellison, seconded by W. C. Krumbein, and approved that the minutes of the 1954 meeting be approved as published in the *Journal of Paleontology*, Volume 28, Number 4 (July 1954).

The following reports were given.

*1. Report of the 1954 Editor of the Journal of Paleontology* (*Grover E. Murray*).—Volume 28 of the *Journal of Paleontology*, issued in conjunction with the Paleontological Society in 1954, contains 890 pages and 100 collotype plates. Published in it are 66 papers; 1 bibliography and index of Foraminifera; 1 bibliography of Fusulinidae; 13 paleontological notes; 6 nomenclatural notes; author and subject indexes; and miscellaneous notes, reviews, and Society records.

Volume 28 represents a decrease of 22 pages and an increase of 9 collotype plates over Volume 27.

The March, July, and November numbers were prepared by your editors on behalf of the S.E.P.M. These numbers contain 458 pages and 48 collotype plates, an increase of 19 pages and 4 collotype plates over corresponding issues of the previous volume. Financial assistance on the cost of certain plates was received from the Bureau of Economic Geology, The University of Texas. Louisiana State University contributed financial assistance in the form of miscellaneous supplies and expenses and by partial payment of the salary of an editorial assistant. Publication of manuscripts was maintained at a rate which permitted publication in 6–9 months.

The March, July, and November issues contained contributions which may be classified as shown in the table at the top of the next page.

Five of these papers are concerned with fossils outside North America; fourteen primarily describe fossil or living forms; four concern phylogeny and/or taxonomy; four are mainly biostratigraphic; three are bibliographic; and one each deals with methods or ecology. In addition there are

| | *Paleozoic* | *Mesozoic* | *Cenozoic* | *Miscellaneous* | *Total* |
|---|---|---|---|---|---|
| Algae | | 1 | | | 1 |
| Coccoliths | | 1 | 1 | | 1* |
| Foraminifera | 4 | | 5 | 2 | 11 |
| Sponges | 1 | | | | 1 |
| Bryozoans | | 1 | | | 1 |
| Mollusks | | 1 | | | 1 |
| Ostracods | 1 | 1 | 1 | | 3 |
| Crinoids | 1 | | | | 1 |
| Holothuroids | 1 | | | | 1 |
| Echinoids | | | 1 | | 1 |
| Graptolites | 1 | | | | 1 |
| Vertebrates | | | 1 | | 1 |
| Miscellaneous | 2 | 1 | 1 | | 4 |
| | 11 | 6 | 10 | 2 | 28 |

* Paper deals with both Mesozoic and Cenozoic forms.

five paleontological notes, five nomenclatural notes, six reviews, and miscellaneous errata, notices, news and events, and Society records.

Considerable time was devoted during the year to general activities related to the Society's financial position. Your editor served as a member of the joint P.S.-S.E.M.P. Committee, which investigated the financial agreement between the two Societies. He also attended The Paleontological Society council meetings in Los Angeles in November, 1954, as the official representative of the S.E.P.M.

Effective December 31, 1954, the incumbent editor, Grover E. Murray, resigned, after completion of a 3-year term.

A. K. Miller and W. M. Furnish assumed duties as co-editors on January 1, 1955.

2. *Report of the Present Editors of the Journal of Paleontology* (*A. K. Miller and W. M. Furnish*).—The general policies of previous editors are being continued, but, as in the past, they may be modified to accord with changing needs. No associate editors have been appointed, and censors can remain anonymous.

Manuscripts approved for publication have been about equal in number and size to those already sent to the printer. Many of the studies handled recently contain a large proportion of diagrammatic figures, which are very helpful to the reader and are relatively inexpensive to print.

The materials passed on to us were in good order, and, with the manuscripts now on hand, we can visualize the Journal about a year in advance.

3. *Report of the Acting Editor of the Journal of Sedimentary Petrology* (*Ralph E. Grim*).—*The Journal of Sedimentary Petrology*, was published in 1954 as Volume 24, Numbers 1 through 4. Number 1 contained 68 pages; Number 3 contained 74 pages; Numbers 2 and 4 contained 80 pages. Fourteen hundred copies of the first three issues were printed, and 1700 copies of the fourth issue were printed. The contents of the volume included 28 technical articles, four notes, one discussion, five reviews, three pages of announcements, abstracts of papers given at the 1954 S.E.P.M. meeting in St. Louis and the 1953 Pacific Coast Section of the S.E.P.M. in Los Angeles, and an index. One and a half pages of advertisements of Society publications were run, and four full page paid advertisements were run.

The distribution of articles, notes, and discussions according to national origin was as follows: United States, 29; England, 1; South Rhodesia, 1; Iraq, 1; and the Netherlands, 1.

The increase in the size of the Journal to a maximum of 80 pages per number has reduced the backlog of manuscripts to about a nine months supply which is a comfortable working margin.

As in the past five years, the University of Illinois has provided a half-time editorial assistant.

Special Publication No. 3 of the Society, the Symposium on *Finding Ancient Shorelines*, is in the hands of the printer and should appear in about two or three months.

4. *Report of the Secretary-Treasurer* (*Samuel P. Ellison, Jr.*).—

BACK VOLUME SALES

(March 1, 1954 to March 1, 1955)

| | |
|---|---|
| Back volumes of the *Journal of Paleontology* | $3,952.03 |
| Back volumes of the *Journal of Sedimentary Petrology* | $1,151.15 |

SPECIAL PUBLICATION SALES

(March 1, 1954 to March 1, 1955)

| | |
|---|---|
| *Turbidity Currents* | $ 205.50 |
| *Bibliography of Otoliths* | $ 20.00 |

PRINTING AND ENGRAVING BILLS FOR 1954

*Journal of Paleontology*

| *Issue* | *Banta Printing Bills* | | *Meriden Engraving Bills* | *Total Printing and Engraving Bills* | *S.E.P.M. Total Printing and Engraving Bills* |
|---|---|---|---|---|---|
| | *Printing* | *Postage* | | | |
| Number 1 (Jan.)* | $ 2,062.26 | $ 53.81 | $ 694.99 | $ 2,811.06 | |
| Number 2 (March) | 2,229.52 | 59.41 | 338.01 | 2,626.94 | $2,626.94 |
| Number 3 (May)* | 2,262.10 | 84.30 | 651.55 | 2,997.95 | |
| Number 4 (July) | 2,425.08 | 63.03 | 744.97 | 3,233.08 | 3,233.08 |
| Number 5 (Sept.)* | 2,799.05 | 89.87 | 990.28 | 3,879.20 | |
| Number 6 (Nov.) | 2,993.39 | 96.75 | 763.95 | 3,854.09 | 3,854.09 |
| | $14,771.40 | $447.17 | $4,183.75 | $19,402.32 | $9,714.11 |
| (1953 Totals) | ($14,059.75) | ($416.93) | ($3,962.96) | ($18,439.64) | ($9,290.46) |

* Odd numbers paid by Paleontological Society.

*Journal of Sedimentary Petrology*

| *Issue* | *Banta Printing Bills* | | |
|---|---|---|---|
| | *Printing* | *Postage* | *Total* |
| Number 1 (March) | $1,013.03 | $ 38.59 | $1,051.62 |
| Number 2 (June) | 1,293.20 | 88.05 | 1,381.25 |
| Number 3 (September) | 1,156.40 | 64.03 | 1,220.43 |
| Number 4 (December) | 1,244.86 | 77.70 | 1,322.56 |
| | $4,707.49 | $268.37 | $4,975.86 |
| (1953 Totals) | ($4,528.45) | ($247.85) | ($4,776.30) |

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

| | *March 1955* | *March 1954* | *March 1953* |
|---|---|---|---|
| 1. S.E.P.M. Membership: | | | |
| Active Members | 800 | 643 | 618 |
| Associates | 285 | 315 | 310 |
| Honorary Members | 2 | 1 | 1 |
| Correspondents | 5 | 5 | 5 |
| TOTAL | 1,092 | 964 | 934 |
| 2. *Journal of Paleontology* Mailing List: | | | |
| S.E.P.M. & Honorary Members | 415 | 386 | 382 |
| S.E.P.M. Associates | 148 | 180 | 181 |
| Subscribers | 570 | 584 | 568 |
| P.S. Members | 615 | 566 | 573 |
| TOTAL | 1,748 | 1,716 | 1,704 |
| 3. *Journal of Sedimentary Petrology* Mailing List: | | | |
| S.E.P.M. Active & Honorary Members | 527 | 408 | 385 |
| S.E.P.M. Associates | 166 | 193 | 189 |
| S.E.P.M. Correspondents | 5 | 5 | 5 |
| S.E P.M. Subscribers | 777 | 596 | 541 |
| TOTAL | 1,475 | 1,202 | 1,120 |

| | | |
|---|---|---|
| 4. Number of pages in 1954 *Journal of Paleontology* | 888 | (910 in 1953) |
| 5. Number of plates in 1954 *Journal of Paleontology* | 100 | (91 in 1953) |
| 6. Total edition of 1954 *Journal of Paleontology* | 2,200 | (2,100 in 1953) |
| 7. Number of pages in 1954 *Journal of Sedimentary Petrology* | 298 | (301 in 1953) |
| 8. Total edition of 1954 *Journal of Sedimentary Petrology* | 1,400* | (1,400 in 1953) |
| New members from Mar. 1, 1954 to Mar. 1, 1955 | 169 | (78, 1953–1954) |
| Transfers to active membership, Mar. 1, 1954 to Mar. 1, 1955 | 57 | (2, 1953–1954) |
| Members and associates dropped for non-payment of dues, 1954 | 28 | (37, 1953) |

* 1,700 copies beginning with December, 1954.

## FINANCIAL STATEMENT FOR THE YEAR ENDED DECEMBER 31, 1954

### CERTIFICATE OF INDEPENDENT PUBLIC ACCOUNTANTS

*The Council, Society of Economic Paleontologists and Mineralogists:*

We have examined the balance sheet of Society of Economic Paleontologists and Mineralogists at December 31, 1954, and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of Society of Economic Paleontologists and Mineralogists at December 31, 1954, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

Tulsa, Oklahoma, January 18, 1955

### SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
### BALANCE SHEET, DECEMBER 31, 1954

| ASSETS | *Total* | *General Fund* | *Publication Fund* |
|---|---|---|---|
| CURRENT ASSETS: | | | |
| Cash | $15,742.04 | $14,510.54 | $1,231.50 |
| Savings account | 2,557.09 | 2,557.09 | — |
| Accounts receivable | 61.10 | 61.10 | — |
| Total current assets | $18,360.23 | $17,128.73 | $1,231.50 |
| PUBLICATIONS: | | | |
| *Journal of Paleontology:* | | | |
| Issues prior to 1954—14,254 journals at 50¢ each (2,265 complete volumes) | $ 7,127.00 | $ 7,127.00 | $ — |
| Issues 1 to 6 of 1954—1,843 journals, at cost | 2,780.33 | 2,780.33 | — |
| Reprints in 1948, Volume 1, 1927—745 volumes, at cost | 1,630.42 | 1,630.42 | — |
| *Journal of Sedimentary Petrology:* | | | |
| Issues prior to 1954—2,706 journals at 50¢ each (780 complete volumes) | 1,353.00 | 1,353.00 | — |
| Issues 1 to 4 of 1954—446 journals, at cost | 403.81 | 403.81 | — |
| Special publications: | | | |
| Turbidity Currents, 584 issues, at cost | 499.38 | — | 499.38 |
| Total publications | $13,793.94 | $13,294.56 | $ 499.38 |
| FURNITURE AND FIXTURES (less reserve, $1,782.26) | $ 1.00 | $ 1.00 | $ — |
| DEFERRED CHARGES | $ 95.07 | $ 60.75 | $ 34.32 |
| | $32,250.24 | $30,485.04 | $1,765.20 |

| LIABILITIES AND SURPLUS | | | |
|---|---|---|---|
| CURRENT LIABILITIES: | | | |
| Accounts payable | $ 347.46 | $ 347.46 | $ — |
| Amount payable to Paleontological Society | 3,774.56 | 3,774.56 | — |
| Accrued printer's charges | 4,380.00 | 4,380.00 | — |
| Accrued payroll taxes | 74.31 | 74.31 | — |
| Total current liabilities | $ 8,576.33 | $ 8,576.33 | $ — |
| DEFERRED CREDITS: | | | |
| Subscriptions to journals (less $2,596.32 payable to Paleontological Society) | $ 6,690.66 | $ 6,690.66 | $ — |
| Subscriptions to special publications | 12.00 | — | 12.00 |
| Membership dues for 1955 and 1956 | 6,707.80 | 6,707.80 | — |
| Total deferred credits | $13,410.46 | $13,398.46 | $ 12.00 |
| SURPLUS, per accompanying statement | $10,263.45 | $ 8,510.25 | $1,753.20 |
| | $32,250.24 | $30,485.04 | $1,765.20 |

(*See also facing page*)

5. *Report of the Research Committee* (*E. C. Dapples, Chairman*).—In accordance with the change in By-Laws, the Research Committee was expanded in number and geographic representation from nine to fourteen. The current list of membership and area representation is as follows:

| | |
|---|---|
| H. A. Lowenstam | California |
| L. E. Workman | Western Canada |
| Bernhard Kummel | New England |
| F. J. Pettijohn | Atlantic Coast |
| E. D. McKee | Southwestern States |
| H. E. Summerford | Rocky Mountains |
| F. B. Van Houten | Atlantic Coast |
| W. C. Bell | Gulf Coast |
| O. L. Bandy | California |
| R. H. Nanz | Gulf Coast |
| L. L. Sloss | North Central States |
| Curt Teichert | New Mexico |
| R. E. Siever | North Central States |

Except for the selection of topic and speakers for the annual symposium, the committee has not undertaken any special project. This year the subject of the symposium, sponsored by the committee, is entitled, "Sedimentary Aspects of Restricted Basin Deposition." Invited speakers are P. D. Krynine, Hugh N. Frenzel, R. M. Garrels, and A. L. Howland.

A new chairman, R. A. Siever of the Illinois State Geological Survey, was selected to serve for the year 1955–56.

6. *Report of the Respresentative on the Glossary of Geologic Terms Committee* (*Willard D. Pye*).—As representative of the S.E.P.M. on the American Geological Institute Glossary Project, meetings of that project committee were attended at the time of the Geological Society of America convention in Los Angeles and at the time of the A.A.P.G. convention in New York.

The present status of the project is that as of the time of the project committee meeting Monday, March 28, about two-thirds of the words for inclusion in the glossary had been defined and were on file in Tulsa where final processing is being handled. A number of the sub-committees have completely finished their work.

As of the Monday meeting indications were that all fields of geology and closely related fields would have their specialized vocabularies represented in the glossary except for the fields of Vertebrate and Invertebrate Paleontology. These groups feel that they cannot complete vocabulary work before the publication deadline.

The work on sedimentation and sedimentary petrology is progressing. A considerable portion of the work is in the final review stage. Some new terms still must be defined. It is hoped that by early summer work will be completed on the sedimentary portion of the project.

Publication plans for the project are that

(*Continued on page 746*)

## SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
## STATEMENT OF INCOME AND SURPLUS
## YEAR ENDED DECEMBER 31, 1954

| | *Total* | *General Fund* | *Publication Fund* |
|---|---|---|---|
| INCOME: | | | |
| Membership dues and subscriptions: | | | |
| *Journals of Paleontology and Sedimentary Petrology* | $ 2,830.00 | $ 2,830.00 | $ — |
| *Journal of Paleontology* | 8,433.82 | 8,433.82 | — |
| *Journal of Sedimentary Petrology* | 5,070.79 | 5,070.79 | — |
| | $16,334.61 | $16,334.61 | $ — |
| Sales of special publication—Turbidity Currents | $ 211.00 | $ — | $ 211.00 |
| Sales of back numbers: | | | |
| *Journal of Paleontology*, Volumes 1 to 28 | $ 3,799.03 | $ 3,799.03 | $ — |
| *Journal of Sedimentary Petrology* | 1,195.81 | 1,195.81 | — |
| | $ 4,994.84 | $ 4,994.84 | $ — |
| Sales of plates | $ 312.78 | $ 312.78 | $ — |
| Advertising | $ 120.25 | $ 120.25 | $ — |
| Donation (from The American Association of Petroleum Geologists) | $ 3,714.00 | $ 3,714.00 | $ — |
| Miscellaneous | $ 230.13 | $ 230.13 | $ — |
| | $25,917.61 | $25,706.61 | $ 211.00 |
| Less: Proportion of 1954 income accrued to Paleontological Society | 2,599.00 | 2,599.00 | — |
| | $23,318.61 | $23,107.61 | $ 211.00 |
| COSTS AND EXPENSES: | | | |
| Cost of printing: | | | |
| *Journal of Paleontology* | $ 9,896.73 | $ 9,896.73 | $ — |
| *Journal of Sedimentary Petrology* | 5,525.02 | 5,525.02 | — |
| | $15,421.75 | $15,421.75 | $ — |
| Expenses: | | | |
| Clerical salaries | $ 5,674.68 | $ 5,674.68 | $ — |
| Employee pension and death benefits plan expense | 117.26 | 117.26 | — |
| Office supplies | 1,200.01 | 1,200.01 | — |
| Postage and express | 1,177.26 | 1,177.26 | — |
| Office rent | 1,500.00 | 1,500.00 | — |
| Telephone | 194.94 | 194.94 | — |
| Audit fee | 200.00 | 200.00 | — |
| Payroll taxes | 267.10 | 267.10 | — |
| Miscellaneous | 551.98 | 551.98 | — |
| | $10,883.23 | $10,883.23 | $ — |
| Adjustment for decrease in inventory of publications | $ 177.27 | $ 105.44 | $ 71.83 |
| | $26,482.25 | $26,410.42 | $ 71.83 |
| NET INCOME (LOSS) | $(3,163.64) | $(3,302.81) | $ 139.17 |
| SURPLUS AT DECEMBER 31, 1953 | 13,427.09 | 11,813.06 | 1,614.03 |
| SURPLUS AT DECEMBER 31, 1954 | $10,263.45 | $ 8,510.25 | $1,753.20 |

it shall go to the printer during the fall of 1955 with publication late in 1955 or early in 1956.

*Note:* Since presenting this report at the annual meeting of the S.E.P.M. in New York, word has been received that the Invertebrate Paleontology vocabulary will be prepared for inclusion in the glossary.

7. *Report of Committee on Invertebrate Paleontology* (*Raymond C. Moore*).—The project to organize and publish the "Treatise on Invertebrate Paleontology" has been guided from its inception by a Joint Committee on Invertebrate Paleontology in which the S.E.P.M. members are Branson, Frizzell, Howell, Knight, Lalicker, Newell, Reeside, Rolshausen, Stenzel, and Weller, with R. C. Moore as Chairman, and N. D. Newell as Executive Member of the Joint Committee. Financial support, mainly for preparation of illustrations, has been furnished by the Geological Society of America in the amount of $25,000.00, now nearly all expended; recently, request for an additional grant was submitted to the Projects Committee for recommendation to the Council of G.S.A.

Plans have been formulated for publication of 22 separate parts with an introduction and index additional. As all S.E.P.M. members should know, two parts have already been published (G on Bryozoa and D on Radiolarians and Tintinnines). Currently, part E on Porifera and Archaeocyatha is in press and is expected to be ready for distribution in early May, 1955.

At the present time, manuscripts representing varying segments of other parts in hands of the editor represent every one of the systematic divisions of the *Treatise* and some 15,000 illustrations for morphological and systematic parts of the text are filed under names of authors in the office at Lawrence. Most nearly ready for publication are the parts concerned with chelicerates (P), coelenterates (F), graptolites (V), and ammonites (L). Additional parts, including the important one on foraminifers (C) are expected to be ready during 1955. Thus, important progress on the project can be reported at this time. Work on all divisions is proceeding as actively as possible.

8. *Report of the A. G. I.* (*C. C. Church and H. N. Fisk*).—The A.G.I. Board of Director's meeting was held Friday, April 1, in New York City. The Directors approved action of the Executive Committee regarding an Earth Science extension service to be conducted in high schools throughout the nation. The Institute will act as sponsor for a five-year period and will work with the National Education Association. It is hoped that funds can be made available through the Ford Foundation. Operating costs will be $75,000.00 per year. This plan was conceived by the Yellowstone-Big Horn Research Association and is now being tested in the high schools of Montana, North Dakota, and South Dakota.

Also approved were the policy statement regarding scientific manpower which was published in the April issue of the *News Letter*, the campaign now underway to enlarge the Institute's reserve fund, and publication of the *News Letter* each month, rather than on the present nine-month basis.

9. *Report of Membership Committee, Gulf Coast Area* (*Stuart A. Levinson*).—During the past year this committee was appointed and has actively pursued its objectives. The committee is made up of W. H. Akers, New Orleans, Louisiana; C. C. Albritton, Jr., Dallas, Texas; T. D. Cook, Corpus Christi, Texas; H. S. Puri, Tallahassee, Florida; R. H. Shaver, University, Mississippi; G. L. Wilde, Midland, Texas; and S. A. Levinson, Houston, Texas, Chairman.

Most of the committee members at their own time and expense have distributed letters soliciting membership in the Society, this in addition to personal contact. The letters were prepared by the individual members of the committee and differ some in content. They all basically contain: (1) Introduction, reason for sending out the letter, and the aim of the Society. (2) Requirements for membership in the Society. (3) The benefits enjoyed by joining the Society. (4) Relationship of National S.E.P.M. to Gulf Coast Section—S.E.P.M. (5) How to handle the application, and to point out that A.A.P.G. members do not need sponsors. I have taken the time to discuss this procedure as it may assist membership committees in other areas to formulate plans for membership drives.

I would like to quote excerpts from letters

recently received from committee members. From R. H. Shaver: "The attached letter is a copy of that which I have sent to 151 geologists in Mississippi and Alabama together with an S.E.P.M. application for membership form." From T. D. Cook: "I was able to contact personally several of the local people engaged in paleontological and sedimentary studies. In October, I sent a letter, copy of which is attached, to all of the people in my area engaged in such studies who were not Society members. As a result of these contacts I am certain that three persons have been admitted to membership and three others appeared ready to submit applications to the Society." From G. L. Wilde: "I am happy to inform you that the organization of the Permian Basin S.E.P.M. Section has greatly encouraged individual affiliation with the main body of S.E.P.M. . . . approximately 150 have requested application blanks for the purpose of joining the main body." In the Florida area prior to the organization of the committee there were seven S.E.P.M. members in the area. Under the leadership of H. S. Puri, membership has increased to 16, which more than doubled representation from that area. The other committee members are just as active and their results as encouraging. There is a normal time lag between contacts and membership and the forthcoming year should continue to reflect the activities of this committee.

10. *Report of the Gulf Coast Section* (*Charles W. Stuckey, Jr.*).—One of the accomplishments of the section since the last annual meeting is the preparation of a report entitled, "The Technique of Catching and Handling Well Samples." The article appeared in two trade journals, and was distributed to 280 drilling contractors, operators, and companies. Eight hundred additional copies are being reprinted and will be given to section members for distribution to drilling rigs.

A committee is now at work correcting some of the evils existing in sample cutting.

A major undertaking called "The Type Locality Project" has begun. A list of 300 stratigraphic units has been compiled for the Gulf Coast Area from South Carolina to the Rio Grande, including those of Mesozoic and Cenozoic age. A report will be made giving a map, accurate directions, lithology, list of fossils, if any, and reference to the original definition.

Representatives have been appointed in each local geological society in our area of operation. Their duties are to secure new members and papers, and to serve the section in any manner possible.

Our organization now includes 227 members, some of whom will become delinquent on April 1. Our treasury balance amounts to $286.74.

The Gulf Coast Section vice-president, E. H. Rainwater, is serving as editor of the Transactions of the Gulf Coast Association of Geological Societies. Robert H. Shaver, one of our members, is associate editor.

It has been suggested that group meetings be held in localities where the membership is sufficiently large. The possibility of this is being investigated.

In our second year of operation, it appears that the section is firmly established. The member's interest is keen. A great deal is expected to be accomplished toward improving the status of paleontologists and mineralogists in the Gulf Coast Area in the remainder of the year.

11. *Report of Pacific Coast Section* (*Harold G. Billman*).—Present membership in the Pacific Section is approximately 200, and, as in the past, is concentrated largely in the Los Angeles Basin and San Joaquin Valley areas. The financial position of the section is excellent.

In the San Joaquin Valley area a Paleontologists' Biostratigraphic Seminar is being sponsored jointly with the Bakersfield College Evening School. The latter is underwriting the cost of this program. To date six meetings have been held and two more are scheduled for the following months. This seminar is of considerable value as it provides an opportunity for Pacific Section members to hear reports of recent developments by outstanding workers in the fields of biostratigraphy and paleontology.

On March 8, 1955, a joint meeting with the Coast Geological Society was held at Santa Barbara, at which time Mr. C. M. Carson discussed the Pliocene and Pleistocene stratigraphy of the Ventura Basin.

An evening meeting is planned for early in September for the Los Angeles Basin area,

and a joint S.E.P.M.—A.A.P.G. evening dinner meeting is scheduled in Bakersfield early in the fall.

A two-day meeting and field trip, to be held jointly with the Pacific Section of the A.A.P.G., is scheduled for May 13 and 14. This program will include a dinner meeting in Bakersfield, at which time Mr. Tennant Brooks will discuss the geology of the Devils Den—McLure Valley area. On the following day a field trip will be conducted to the area where the geology may be seen and fossils collected.

In November the Pacific Section will participate in the joint annual fall meeting of the A.A.P.G.—S.E.G.—S.E.P.M. in Los Angeles. At this time the Pacific Section of the S.E.P.M. will hold its annual evening dinner meeting, and a morning technical session the following day.

12. *Report of the Permian Basin Section (Harold L. Williams).*—The Permian Basin Section of the S.E.P.M. was formed during the past year. The history of the formation of this section and accomplishments to date are as follows:

June 21, 1954: Petition requesting authorization by charter of the proposed Permian Basin Section in compliance with S.E.P.M. By-Laws, Article VII. This petition was signed by John Emery Adams, John W. Skinner, R. V. Hollingsworth, Maria F. Spencer, Harold L. Williams, Hugh N. Frenzel, Millard B. Arick, Lloyd C. Mills, Frederick L. Stead, and Garner L. Wilde.

August 5, 1954: Notification of acceptance of the petition by the S.E.P.M. Council.

August 9, 1954: An Advisory Committee for the Permian Basin Section of five members was selected as follows: John Emery Adams, R. V. Hollingsworth, E. Russell Lloyd, Wallace E. Pratt, and John W. Skinner.

A Steering Committee for the Permian Basin Section of five members was selected as follows: Walter W. Roye, Tom Schneider, Ed. A. Vogler, Harold L. Williams, and Garner L. Wilde, Chairman.

During August about 2000 circulars announcing the formation of the Permian Basin Section was sent to all geologists in an area west of a line connecting Dallas and Austin to Arizona and north to the north line of New Mexico and Arizona. About 325 persons answered the circular and sent their membership fee of $1.00, thus becoming charter members.

Garner L. Wilde is to be especially commended for his work in organizing the Steering Committee and the Advisory Committee that led to the organization of the Permian Basin Section. He was almost wholly responsible for getting information together, circulating the petition, sending out circulars, announcing the formation of the Section, sending out ballots, and doing all the spade work necessary to get the Section organized.

We wish to acknowledge with gratitude the $200.00 loan from the West Texas Geological Society to the Steering Committee to defray expenses of getting the Section started.

January 6, 1955: A Nominating Committee, consisting of John Emery Adams, E. Russell Lloyd and W. A. Waldschmidt, was formed and asked to select at least two nominees for the offices of President, Vice-President, and Secretary-Treasurer.

January 17, 1955: The Nominating Committee chose the following as candidates for office:

*President:* HAROLD L. WILLIAMS, GARNER L. WILDE
*Vice-President:* VIRGIL E. BARNES, FRANK B. CONSELMAN
*Secretary-Treasurer:* HUGH N. FRENZEL, MARIA F. SPENCER

January 24, 1955: Mail ballots were sent to all charter members, with notification that only those ballots received before February 15, 1955, would be counted.

February 15, 1955: The following officers were elected:

*President:* HAROLD L. WILLIAMS
*Vice-President:* VIRGIL E. BARNES
*Secretary-Treasurer:* HUGH N. FRENZEL

February 25, 1955: The following committee chairmen were appointed:

*Constitution:* BERTE R. HAIGH
*Program:* GEORGE T. SCHMITT
*Field Trip:* GARNER L. WILDE
*Editor:* R. V. HOLLINGSWORTH

March 15, 1955: At the first official meeting of the Executive Council (the first year Executive Council consisting of elected officers, advisory committee, and committee

chairmen), it was decided that: (1) An annual field trip would be held. (2) Evening programs would be held at irregular intervals—depending upon speakers available. These meetings will be informal, restricted to members and dependent upon local speakers. (3) An annual meeting will be held in the fall with the locality changing each year. (4) Officers will be installed at the end of the annual meeting. (5) The annual meeting may coincide with the field trip. (6) The organization will be, as John Emery Adams, one in which the members can enjoy geology that is not slanted toward the oil industry. Our program will be built around study groups working on problems of stratigraphy, sedimentation, paleontology, lithology, or any other phase of geology that a group may care to undertake. (7) Present officers will continue in office until the annual fall meeting of 1956.

13. *Report on the Journal of Paleontology Index* (*Hans E. Thalmann*).—Thanks to the last year's report on the status of the Comprehensive Index to the first twenty-five volumes of the *Journal of Paleontology* (28th Annual Meeting, St. Louis, Missouri), volunteers offered their help in bringing this project to a successful termination. Miss Louise Jordan, Miss Myra Keen, Mrs. Doris Malkin Curtis, Miss Eleanor T. Caldwell, and R. L. Langenheim, Jr., actively cooperated in indexing one or two volumes on 3×5 index cards. Mrs. Augusta Hasslock Kemp and Hubert C. Skinner are standing by in order to help out if and when required. To all of them the Society extends its most cordial appreciation and thanks. Hubert C. Skinner has been asked by the President to take over, year by year, the next 10 volumes of our Journal in order that the indexing of the next ten volumes (26 to 35) might appear in print considerably quicker than is the case with the present index of the first twenty-five volumes.

Within the next three months, or about the middle of this year, it is hoped that the Index will be completed and ready for the printer. Marianne and Heidi Thalmann are at present actively engaged in arranging alphabetically the many thousands of cards and thus preparing the "card-manuscript" for the final printing.

14. *Report on History of S.E.P.M.* (*Marcus A. Hanna*).—The work on the history of the Society of Economic Paleontologists and Mineralogists is progressing slowly. Many of the old records are difficult to find or possibly now are non-existent. In many cases only one side of the correspondence has been secured. I believe the early part of the history will be the most difficult but ready for round-robin additions and corrections by the next meeting.

15. *Report of the Advisory Committee on Radioactive Mineral Exploration* (*Harold N. Fisk, S.E.P.M. Representative*).—The American Association of Petroleum Geologists' Advisory Council on Radioactive Mineral Exploration met in Dallas, Texas, on November 15, 1954. It was learned that in a four-state area, including Montana, Wyoming, Utah, and Nevada, 17 major oil companies and 5 minor companies or independents are actively engaged in gamma logging of seismic shot holes, either using Atomic Energy Commission equipment or allowing personnel of the Commission to probe the holes. In the discussions of the probes used in uranium exploration, the need for a dependable instrument with a suitable recording device was stressed. The present instrument is hand-operated and in some other respects is not highly satisfactory. Discussed also was the "Multiple Use Law," wherein leases may be simultaneously granted to a single or several companies for uranium mineral rights and for oil and gas rights. It was pointed out that a lease assigned on Federal lands for petroleum exploration does not *per se* include rights for uranium exploration; and vice versa. Application for each must be made independently of the other. This information and other data, such as pertinent publications, may be found in Circular Six of the Advisory Committee, which was released on February 24, 1955.

16. *Report of Committee on S.E.P.M.—P.S. Mutual Relations* (*R. Dana Russell*).—The S.E.P.M.—P.S. Mutual Relations Committee was appointed by S.E.P.M. President Hans Thalmann in May and June, 1954, with the following membership: Kenneth E. Caster, Robert H. Dott, Raymond C. Moore, Grover E. Murray, Henryk B. Stenzel, and R. Dana Russell, Chairman. Harry S. Ladd was added later

at my request. The Committee was charged by President Thalmann with examining the present financial arrangement between the two Societies incident to joint publication of the *Journal of Paleontology*, determining whether this arrangement was equitable, and recommending changes if it was not considered so. The present arrangement was established in 1938 and has not been critically reviewed since. After careful consideration the following agreement was reached and approved by both the S.E.P.M. and the P.S. Councils.

"1. Income and expenses shall be apportioned on an annual cash calendar year basis; income shall include funds received during the period January 1 through December 31 of each year, and expenses shall include those items paid out during the same period.

"2. The Society of Economic Paleontologists and Mineralogists (hereinafter known as the S.E.P.M.) shall receive all income from:

a. Dues of members and associates of S.E.P.M.
b. Contributions to S.E.P.M.
c. The first 300 non-member subscriptions to the *Journal of Paleontology*.
d. Sale of all back numbers of Volumes 1 through 8 of the *Journal of Paleontology*.
e. Sale of plates in reprints, plate subscriptions, and separate back plates of S.E.P.M. issues of the *Journal of Paleontology*.
f. Activities of the S.E.P.M. not connected with joint publication of the *Journal of Paleontology* (e.g., publication of the *Journal of Sedimentary Petrology*, special publications, etc.).

"3. The S.E.P.M. shall pay all of the following expenses:

a. Printing, engraving, and editorial expenses for the S.E.P.M. issues of the *Journal of Paleontology*.
b. Printing, engraving, and editorial expenses for other publications of the S.E.P.M.
c. Operating expenses supporting exclusively (or essentially so) activities of the S.E.P.M. other than joint publication of the *Journal of Paleontology*.

"4. The Paleontological Society (hereinafter known as the P.S.) shall receive all income from:

a. Dues of members of the P.S.
b. Contributions to the P.S.
c. Sale of plates in reprints, plate subscriptions, and separate back plates of P.S. issues of the *Journal of Paleontology*.
d. Activities of the P.S. not connected with joint publication of the *Journal of Paleontology*.

"5. The P.S. shall pay all of the following expenses:

a. Printing, engraving, and editorial expenses for the P.S. issues of the *Journal of Paleontology*.
b. All other expenses supporting exclusively (or essentially so) activities of the P.S. other than joint publication of the *Journal of Paleontology*.

"6. Income from the following sources shall be apportioned equitably between the two Societies, using number of issues and total pages of the *Journal of Paleontology* published by each Society as the primary consideration in the apportionment:

a. Non-member subscriptions to the *Journal of Paleontology* over 300.
b. Sale of back numbers of Volume 9 through the current volume of the *Journal of Paleontology*.
c. Advertising in the *Journal of Paleontology*.

"7. The following expenses shall be apportioned equitably between the two Societies, using publication distribution figures (publication items times mailing lists) as the primary consideration in the apportionment:

a. Direct joint charges to the *Journal of Paleontology* (e.g., Index expense).
b. General office and operating expenses of the S.E.P.M. Headquarters Office contributing to the joint publication of the *Journal of Paleontology*.

"8. Apportionment of the income and expense items covered in paragraphs 6 and 7 above shall be accomplished as follows:

a. Between September 30 and November 1 of each year the S.E.P.M. Headquarters Office shall furnish the Council of each Society with a detailed statement of income, expenses, and publication distribution figures for the preceding year (from October 1 of the previous year through September 30 of the current year). On the basis of these figures, the S.E.P.M. Headquarters Office will also recommend to the two Councils an equitable distribution of these items.
b. The statement of income, expense, and distribution figures, together with recommendations of S.E.P.M. Headquarters shall be reviewed by a committee composed of the P.S. Secretary, S.E.P.M. Secretary, and S.E.P.M. Business Manager, and this committee shall determine and recommend to the two Councils an equitable apportionment of income and expenses.

c. Prior to December 31 of each year, the Councils of the two Societies shall agree upon an equitable distribution and shall inform the S.E.P.M. Headquarters Office of their decision.

d. Between January 1 and 31 of the next year, the S.E.P.M. Headquarters Office shall apportion the income and expenses of the calendar year just past on the basis of the decision of the two Councils. This apportionment will be reviewed by the auditor making the annual audit of S.E.P.M. finances, using a copy of this agreement and the apportionment agreement of the two Councils for the calendar year just past.

"9. This memorandum was ratified at a joint meeting of the Councils of both Societies in Los Angeles, California, October 31, 1954. It shall apply to apportionment of income and expenses for calendar year 1955, and subsequently until modified or revoked."

17. *Report on Finding Ancient Shorelines* (*Ralph E. Grim*).—Special Publication Number 3, *Finding Ancient Shorelines*, is now in the hands of the printer and authors will receive galley proofs shortly. It contains papers by six authors and will total about 132 pages. The entire volume will be comparable in style to *Turbidity Currents*.

The manuscript was edited by H. W. Menard and styled for the printer by the editor. It is proposed to print 2000 copies at an estimated cost of $3,307.00. The volume should appear in two or three months.

18. *Report on Recent Marine Sediments* (*Parker D. Trask*).—*Recent Marine Sediments*, originally published by the A.A.P.G. in 1939, is being reprinted by the S.E.P.M. by the photo-offset process. This means that the original plates of the book are reproduced without revision. A few of the photographs in the original edition were redrawn as line drawings in order to assure better reproduction. A new chapter entitled, "Statement of Progress in the Study of Recent Marine Sediments, 1939–1954," has been added in an effort to bring the book up to date. This chapter contains a list of 500 citations to the literature that has appeared in the last 15 years. The price of the book will be $4.00 for S.E.P.M. and A.A.P.G. members and $5.00 for others. An edition of 2000 copies is being printed. The book is now in press and should be ready for distribution sometime during the summer.

19. *Presidential Summary* (*Hans E. Thalmann*).—During the term of office of the President, the highlight was the establishment of a new regional section of the S.E.P.M.—The Permian Basin Section, with Garner L. Wilde as its first president. Together with the Gulf Coast Section, formed a year earlier and the Pacific Coast Section, the activities in the fields of paleontology and sedimentology are greatly increased, and it is to be hoped that more regional sections will be founded throughout the country.

The following appointments were made during the year: At the beginning of 1955 A. K. Miller and W. M. Furnish as editors of our *Journal of Paleontology*, succeeding Grover E. Murray. Parker Trask took over the editorship of the reprinting of *Recent Marine Sediments*, adding new chapters and progressing with his work in such a way that this volume will be out within a short time. R. Dana Russell with his committee prepared the mutual financial agreement between our Society and the Paleontological Society, which was signed by the officers of both Societies last November and is now in effect. A renewed drive for membership was inaugurated, and, thanks to the activity of the various membership committees throughout the country, our membership was increased. The Research Committee was increased to 14 members, and chairmen and co-chairmen were appointed for the Paleontology Session, the Mineralogy Session, and the two Symposia at our present New York meeting. Francis J. Pettijohn was appointed to serve as our representative on the National Research Council, and William A. Kelly represented our Society at the 100th Anniversary of the Founding of the Michigan State College early this year. Jesse J. Galloway was proposed and elected to honorary membership in our Society.

Two resignations had to be accepted: Grover E. Murray as editor of our *Journal of Paleontology*, replaced by A. K. Miller and W. M. Furnish; and Mrs. Nadine Jackson, our Headquarters Secretary in Tulsa, replaced by Mrs. Ruth Tener. The President offers his most cordial thanks for splendid cooperation and advice received from his colleagues on the Council, from the members of the various committees, from our Busi-

ness Manager, Robert H. Dott, and extends the thanks on behalf of the Society to Grover E. Murray and Mrs. Jackson.

Our Society is in a healthy state and position, vigorous and active in our chosen fields of paleontology and sedimentology. Much can still be accomplished if and when every member of the Society helps to achieve our noble goal to "promote the science of stratigraphy through research in paleontology and sedimentary petrology, especially as these relate to the development of knowledge of the geology of petroleum."

It was moved by R. Dana Russell, seconded by R. R. Shrock, and approved that the foregoing reports be accepted.

The meeting was then turned over to incoming President Francis J. Pettijohn.

A. R. Loeblich brought up the question of ways and means of securing Russian reprints. After discussions by Loeblich, A. K. Miller, Francis Pettijohn and Stuart Levinson, it was generally agreed that possibly the only approach was directly through individuals.

The Resolutions Committee, composed of A. K. Miller, Godfrey Kaufmann, and L. L. Sloss, presented the following "Resolutions of Thanks":

BE IT RESOLVED THAT in behalf of the Society we extend an expression of our sincere thanks to the following:

TO FRANCIS J. PETTIJOHN, chairman, and the members of the S.E.P.M. Technical Program committee, and to the speakers for the high quality of the papers on the 1955 program;

TO E. C. DAPPLES, chairman of the Research Committee, and the members of his committee, for the excellent research symposium for the 1955 meeting;

TO M. L. THOMPSON and R. R. SHROCK, for planning and arranging the sessions on paleontology and mineralogy, respectively;

TO WILLIAM S. HOFFMEISTER for arranging the very fine symposium on "Spores, Pollen, and Related Materials";

TO BROOKS FLEMING ELLIS, as general chairman of the S.E.P.M. Convention, for his capable handling of the details of the meeting;

TO G. M. KNEBEL, general chairman of the convention, and to the chairmen and members of all the convention sub-committees for effective leadership and assistance in organizing the New York meeting;

TO R. DANA RUSSELL, and his committee on S.E.P.M.—P.S. Mutual Relations, for his untiring efforts in obtaining a satisfactory arrangement with the Paleontological Society and in working out details that would be most equitable to both Societies;

TO GROVER MURRAY, for his years of outstanding service to the Society as editor of the *Journal of Paleontology;*

TO MRS. NADINE JACKSON, who resigned as Headquarters Secretary October 1, 1954, after nine years with the Society, for her interest in the S.E.P.M. and her relentless devotion to duty;

TO THE EXECUTIVE COMMITTEE OF THE A.A.P.G., for appropriating $1,500.00 as office rent for the Society Headquarters at Tulsa, and $3,163.64 to cover the Society's 1954 operating deficit.

AND TO THE STATLER HOTEL for providing excellent meeting and Headquarters facilities.

It was moved by R. R. Shrock, seconded by A. R. Loeblich, and approved that the above Resolutions be adopted.

The business session adjourned at 6:00 P.M., Tuesday, March 29, 1955.

# REVISED CONSTITUTION AND BY-LAWS

(APPROVED JUNE 12, 1955, BY REFERENDUM)

## THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

A DIVISION OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

## CONSTITUTION

### ARTICLE I. NAME

The Society shall be known as the Society of Economic Paleontologists and Mineralogists.

### ARTICLE II. OBJECT

The object of the Society shall be to promote the science of stratigraphy through research in paleontology and sedimentary petrology, especially as these relate to development of knowledge of the geology of petroleum.

### ARTICLE III. MEMBERSHIP

1. The Society shall be composed of active members, associate members, honorary members, correspondents, and patrons.

2. Active members shall be persons engaged in paleontologic, petrographic, or stratigraphic studies as applied to the geology of petroleum and who have been duly elected active members, juniors, or associates in the American Association of Petroleum Geologists.

Active and honorary members only shall be known as members.

3. Associate members shall be known as associates. Any person engaged in paleontologic, petrologic, or stratigraphic studies that have application to the geology of petroleum is eligible for associate membership. Associates shall enjoy all the privileges of membership in the Society, save that they shall not hold office, sign applications for membership, or vote.

4. Honorary members shall be persons of distinguished achievement whose contributions to paleontology, petrology, and stratigraphy have an application to the geology of petroleum.

5. Correspondents shall be persons not resident in North America who have made distinctive contributions to paleontology, petrology, and stratigraphy that have application to the geology of petroleum.

6. Patrons shall be persons who have bestowed important favors on the Society.

### ARTICLE IV. OFFICERS

1. Executive authority of the Society is vested in a council consisting of six members, duly elected officers, as follows: president, vice-president, secretary-treasurer, the past-president, and the editor of each of the two Journals.

2. The president shall discharge the usual duties of a presiding officer at all meetings of the Society and council.

3. The vice-president shall assume the duties of the president in case of his absence.

In the event of the absence from the meetings of both president and vice-president, the duties of presiding officer shall fall upon one of the other members of the council in the following order: past-president, secretary-treasurer.

4. The secretary-treasurer shall keep records of the proceedings of the Society, and a complete list of the membership. He shall attend to the preparation and mailing of notices and other materials required in the business of the Society. The secretary-treasurer shall have custody of all funds of the Society, and shall keep a detailed account of receipts and disbursements.

5. The council shall consider all nominations for membership and pass on the qualifications of the applicants; may elect honorary members, correspondents, and patrons; shall have control and management of the affairs and funds of the Society; shall determine the manner of publication and pass on the material presented for publication; and shall designate the place of the annual meeting. It is empowered to establish a business headquarters for the Society and to employ such persons as are needed to conduct the business of the Society.

6. Elections shall be held annually to select a president, vice-president, secretary-treasurer, and the editors.

### ARTICLE V. MEETINGS

1. The Society shall hold at least one stated meeting a year, which shall be designated as the annual meeting. The time and place of the annual meeting shall be designated by the council, but in general, it shall be held in connection with the annual meeting of The American Association of Petroleum Geologists.

2. The annual meeting shall be devoted to the reading and discussion of scientific papers, to the transaction of Society business, and other appropriate functions.

3. The program for the annual meeting shall be arranged by the council, or under its direction.

### ARTICLE VI. SECTIONS

Local sections of the Society may be established according to provisions of the by-laws.

### ARTICLE VII. AMENDMENTS

The constitution may be amended by a two-thirds vote of returned mail ballots received by the secretary-treasurer sixty days after proposal of amendments with provision for vote is mailed to the membership; provided that the proposed amendment has been signed by at least twenty members, and provided further that the proposed amendment must first have the approval of the council and the executive committee of The American Association of Petroleum Geologists.

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## BY-LAWS

### ARTICLE I. DUES

1. The fiscal year of the Society shall correspond with the calendar year.

2. The annual dues of members and associates of the Society who desire only the *Journal of Paleontology* shall be eight dollars ($8.00). The annual dues of members and associates who desire only the *Journal of Sedimentary Petrology* shall be five dollars ($5.00). Members and associates may receive both Journals by the payment of thirteen dollars ($13.00). Members of the Society who are also members of the Paleontological Society and receive the *Journal of Paleontology* through the latter Society, may retain membership in the Society of Economic Paleontologists and Mineralogists by the payment of one dollar ($1.00) per year dues. The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before September 1 of each year, stating the amount of annual dues and the penalty and conditions for default of payment. Members and associates who shall fail to pay their annual dues by January 1 shall not receive further copies of either Journal, nor shall they be privileged to buy Society publications at special discounts made to the membership, until such arrears are met.

3. The council may from time to time elect as honorary members, correspondents, and patrons, candidates who have been nominated by a majority vote of the research committee. A vote of four members of the council shall be required for election. Honorary members, correspondents, and patrons shall not be required to pay annual dues.

### ARTICLE II. DUTIES AND PRIVILEGES OF MEMBERS

1. Members and associate members dropped for non-payment of dues may apply to the council for reinstatement, and, provided settlement is made of any outstanding indebtedness for publications and other charges approved by the council, may be reinstated by vote of four members of the council.

2. Members shall be eligible to receive publications of the Society at special subscription rates as authorized by the council or as provided in these by-laws.

3. The council is authorized to transmit without charge such publications as it may direct to honorary members, correspondents, and patrons.

4. Only active and honorary members shall have the right to vote in electing officers and in transacting the business of the Society.

### ARTICLE III. OFFICERS

1. Nominations for officers shall be made in the following manner. Prior to September 1 of each year, the president shall designate two nominating committees, instructing each committee to submit nominations for

president, vice-president, secretary-treasurer, and editors, these nominations to be in the secretary's hand before September 15. If desired, the same persons may be nominated by the two committees for the offices of secretary-treasurer and editor of each Journal, respectively, but nominations for president and vice-president shall not include the name of the same person on the two slates. The nominations of the first committee to file its report will have precedence in case of overlapping nominations and the other committee shall then be requested to change its nominations.

2. Ballots containing the nominations for officers, alphabetically arranged under each office, shall be prepared by the secretary-treasurer and mailed to each member of the Society on or before October 1. Neither the ballot nor the enclosing envelope need contain the name of the voting member, but an outer envelope that contains the sealed ballot must bear the name of the voting member. The returned ballots received by the secretary-treasurer on or before December 1 shall be counted by him, and if requested, shall be submitted to recount by the council. A plurality of the votes received for any office constitutes election.

3. If, after his election by the regular ballot, the president shall not be able to discharge the duties of his office, because of death or resignation, the duly elected vice-president shall then assume the duties and title of president with all of the authority vested in him by the Constitution. In the event the vice-president shall not be able to assume said duties, then the succession shall be in the following order: past-president, secretary-treasurer. If none of the above mentioned members of the council shall be able to assume the office of the president, then a special election shall be held in which at least two qualified members, nominated by the council, shall be voted upon by the membership by means of a special mailed ballot. Any vacancies in the normally constituted council caused by such succession or for any other reason may be filled with a temporary appointment by the council.

4. Nominees for the office of president shall be active members in good standing, who shall have served (or may be serving concurrently at the time of nomination) as vice-president, secretary-treasurer, chairman of the Research Committee, or editor of one of the Society's official publications.

5. The vice-president shall be the officer of the council responsible for arrangements for the annual meeting, including selection of program chairmen, and shall keep in close contact with the Research Committee and others concerning technical papers and symposia to be presented.

### ARTICLE IV. PUBLICATIONS

1. There shall be two editors, one for the *Journal of Paleontology* and one for the *Journal of Sedimentary Petrology*. The editors shall be in charge of editorial business of their respective Journals. Each shall submit an annual report of such business, shall have authority to solicit papers and material for such Journals, and may appoint associate or co-editors.

2. The *Journal of Paleontology* and the *Journal of Sedimentary Petrology* are designated as official publications of the Society. The council is not authorized to initiate and publish other periodicals.

3. A publication fund may be established consisting of an assignment of a portion of dues as designated by the council, and such donations as are specifically made for that purpose. The council is authorized to provide special publications from this fund as may be deemed desirable, and to fix terms for sale or other distribution of these publications.

### ARTICLE V. FINANCIAL METHODS

1. No financial obligations shall be contracted without express sanction of the Society or council, but all ordinary incidental running expenses have sanction without special action.

2. Statements of accounts charged to the Society, other than miscellaneous running expenses, shall be approved by the president before the secretary-treasurer pays the amount out of funds of the Society not otherwise appropriated, and the receipted bill shall be held as the secretary-treasurer's voucher.

3. The secretary-treasurer shall have charge of the financial affairs of the Society and shall annually submit reports as secre-

retary-treasurer covering the fiscal year. He shall receive all funds of the Society, and, under the direction of the council, shall disburse all funds of the Society. He shall cause an audit to be prepared annually by a public accountant at the expense of the Society. He shall give a bond, and shall cause to be bonded all employees to whom authority may be delegated to handle Society funds. The amount of such bonds shall be set by the council and the expense shall be borne by the Society. The funds of the Society shall be disbursed by check as authorized by the council.

### ARTICLE VI. BUSINESS REPRESENTATIVES

The president and the secretary-treasurer of the Society shall act as business representatives of the Society in the business committee of The American Association of Petroleum Geologists. These representatives shall conduct such business with the executive committee of the Association as is of mutual interest to the Society and the Association in the interims between the annual meetings of the Society and the Association. Approval of the action of these representatives on the part of the Society during any year is reserved to the council in session at the annual meeting at the close of that year. Questions remaining unsettled between the representatives of the Society and the executive committee of the Association shall be considered in a joint meeting of the council of the Society or its authorized representatives and the executive committee of the Association at the annual meeting of the Association at the close of the interim period during which such questions have arisen.

### ARTICLE VII. SECTIONS

1. The establishment of local sections of the Society may be authorized by unanimous vote of the council approving a petition for such establishment signed by ten members of the Society. Such local sections may elect officers, conduct meetings, and engage in other scientific activities, but shall not be entitled to special representation in general Society affairs.

2. The council is authorized and directed to withdraw the charter of any established local section if there is evidence that it has become inactive.

### ARTICLE VIII. DIRECTORS OF AMERICAN GEOLOGICAL INSTITUTE

1. The president and the past president shall be directors of the American Geological Institute, the past-president being the senior director. They shall represent the Society on said Institute. The term of office as directors shall coincide with their term of president and past-president.

2. In the event of a vacancy by resignation, death, or other causes among the two directors who represent the Society on said Institute, the president of the Society shall nominate a director from the ranks of active members of the Society, and this director shall complete the unexpired term.

### ARTICLE IX. REPRESENTATIVE ON NATIONAL RESEARCH COUNCIL

At the expiration of each three-year term, the president shall appoint a representative on the National Research Council to serve for a term of three years.

### ARTICLE X. RESEARCH COMMITTEE

1. The objectives and duties of the Research Committee shall be to foster and encourage research; to advise the Society and council on research activities which may concern the Society, or which may be recommended or initiated under its sponsorship; to develop a symposium for the annual meeting if so requested; to select recipients for Best Paper Awards each year for each Journal; to nominate candidates for honorary members, correspondents, and patrons; and to deal with any other matters referred to it from time to time by the president or the council.

2. The activities of the Committee shall be directed by a chairman and a vice-chairman, to be appointed by the president from the members of the Committee. In the event either of these offices is vacated for any reason, the president shall appoint a qualified replacement of the unexpired term.

3. Membership of the Committee shall be appointed by the president from members and associates of the Society. The Committee shall consist of fourteen mem-

bers, but this total may be changed at the discretion of the council. Two committee members, preferably one paleontologist and one mineralogist, shall be chosen from each of several geographic regions to be selected by the council. In addition, advisory members may be appointed from foreign areas. The terms of appointment of members and advisory members shall be for three years. Appointments shall be staggered, with the junior member from any region serving at least one year with the senior member from that region. If vacancies develop on the Committee the president shall make suitable appointments for the unexpired term.

ARTICLE XI. AMENDMENTS

The by-laws may be amended at any annual business meeting by two-thirds vote of the members present, or by mail ballot sent to the members, in which case two-thirds of the returned ballots received in sixty days after mailing must approve the amendment in order to make it effective. Any proposed changes to the by-laws must first have the approval of the council.

## ANNOUNCEMENT CONCERNING S.E.P.M. PROGRAM OF CHICAGO MEETING APRIL, 1956

The Society of Economic Paleontologists and Mineralogists is planning a program for the Chicago 1956 meeting that will consist of the following:

1. A joint session with the A.A.P.G.
2. A single half-day session of volunteered paleontological papers with Charles Collinson, Illinois State Geological Survey, Urbana, as Chairman.
3. A single half-day session of volunteered papers on sedimentary mineralogy and petrology, sedimentology, and stratigraphy, with Lewis Cline, University of Wisconsin, Madison, as Chairman.
4. A general session, if necessary, of volunteered papers, with Lewis Cline as Chairman.
5. A symposium on "Directional Properties of Sedimentary Rocks" to be organized by the Research Committee, with Ray Siever, Illinois State Geological Survey, Urbana, as Chairman.
6. A symposium on "Paleoecology," with Harry S. Ladd, U. S. Geological Survey, Washington, and Bernhard Kummel, Harvard University, Cambridge, as Co-Chairmen.

All persons who are interested in submitting papers for the program, or who have suggestions regarding the symposia, should write directly to the respective Chairman of the particular session.

November 15 has been set as a deadline for submitting papers and abstracts for any part of the program. We earnestly solicit your cooperation in helping us to organize and carry through what we hope will be one of our outstanding programs.

ROBERT R. SHROCK
*Vice President*

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